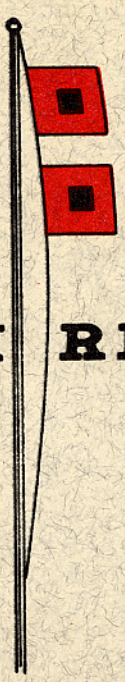
G. F. Blake

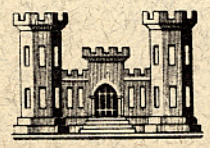
HURRICANE SURVEY



INTERIM REPORT

PAWCATUCK

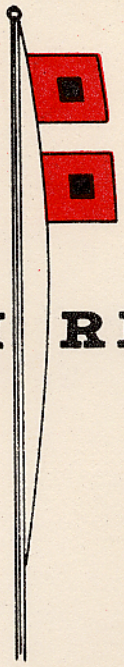
CONNECTICUT



U.S. Army Engineer Division, New England
Corps of Engineers
Boston, Mass.

6 OCTOBER 1958

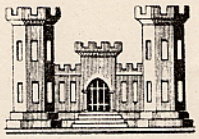
HURRICANE SURVEY



INTERIM REPORT

PAWCATUCK

CONNECTICUT



U.S. Army Engineer Division, New England
Corps of Engineers
Boston, Mass.

6 OCTOBER 1958

TABLE OF CONTENTS

TABLES

PLATES

APPENDICES

APPENDICES - TABLES

APPENDICES - PLATES

GLOSSARY

HURRICANE SURGE: the mass of water causing an increase in the elevation of the water surface above predicted astronomical tide at the time of a hurricane; it includes wind setup; sometimes the maximum increase in elevation is referred to as the surge.

HURRICANE TIDE: the rise and fall of the water surface during a hurricane exclusive of wave action.

KNOT: a velocity equal to one nautical mile (6080.2 feet) per hour (about 1.15 statute miles per hour).

PONDING: the storage of water behind a dike or wall from local runoff.

SPRING TIDE: a tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

STANDARD PROJECT HURRICANE: A storm that may be expected from the most severe combination of meteorologic conditions that are considered reasonably characteristic of the region involved, excluding rare combinations.

STILLWATER LEVEL: the elevation of the water surface if all wave action were to cease.

STORM SURGE: same as "hurricane surge".

SYLLABUS

The Division Engineer finds that a serious problem of flooding from hurricanes and storms exists in the principal industrial area of Pawcatuck, Connecticut. The acuteness of the problem is indicated by the fact that total flood damages of over $2,000,000, at 1958 price levels, would result from a recurrence of the two recent severe hurricanes, September 1938 and August 1954, in the area of proposed protection.

The Division Engineer recommends the construction of a dike and land wall system extending along the west bank of the Pawcatuck River which would provide local protection for the principal industrial area of Pawcatuck, in the Town of Stonington, Connecticut. The estimated first cost is $595,000, of which $419,000 is the cost to the United States.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
150 CAUSEWAY STREET
BOSTON 14, MASS.

6 October 1958

NEDGW

SUBJECT: Interim Report on Hurricane Survey,
Pawcatuck, Connecticut

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.
ATTENTION: ENGWF

AUTHORITY

1. This report is submitted in partial compliance with authorization contained in Public Law 71, 84th Congress, 1st session, adopted 15 June 1955, which reads:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in view of the severe damage to the coastal and tidal areas of the eastern and southern United States from the occurrence of hurricanes, particularly the hurricanes of August 31, 1954, and September 11, 1954, in the New England, New York, and New Jersey coastal and tidal areas, and the hurricane of October 15, 1954, in the coastal and tidal areas extending south to South Carolina, and in view of the damages caused by other hurricanes in the past, the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, is hereby authorized and directed to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred.

SEC. 2. Such survey, to be made under the direction of the Chief of Engineers, shall include the securing of data on the behavior and frequency of hurricanes, and the determination of methods of forecasting their paths and improving warning services, and of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed

breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required."

EXTENT OF INVESTIGATION

2. DESCRIPTIVE SUMMARY OF STUDIES

This interim report of survey scope presents the results of an examination and survey of hurricane and other storm-induced tidal flooding in the principal industrial section of Pawcatuck, Connecticut. It is one in a series of reports which, when completed, will constitute a survey of the entire coastal area of New England subject to tidal flooding due to hurricanes and other great storms.

This report includes data on climatology, hydrology, and tidal flood damages; a summary of the historical occurrences of hurricanes and other severe storms; and a description, together with estimates of costs and benefits, of a recommended plan of improvement which will provide protection against tidal flooding, as well as fresh water flooding.

Field work has consisted of flood damage investigations, topographic and hydrographic surveys in the area of considered protective works, and subsurface explorations to determine the nature and characteristics of underlying material.

3. COORDINATION

State officials and local interests have been consulted frequently during the course of the study, and the work has been coordinated and discussed with appropriate Federal agencies. The views of local interests were considered in arriving at a practicable and economic means of providing needed protection. A public hearing has been held to acquaint all interested parties with the results of the survey and to enable them to present their views and comments thereon. Coordination with other agencies is discussed in further detail in paragraph 74.

PRIOR REPORTS

4. HURRICANE REPORTS

There are no previous reports by the Corps of Engineers on the specific subject of hurricane protection for the Pawcatuck area. Part Two, Chapter XXXIX (unpublished) of the report (Senate Document No. 14, 85th Congress, First Session), on the "Land and Water Resources of the New England-New York Region", prepared by the New England-New York Inter-Agency Committee, pursuant to

Presidential directive of October 9, 1950, includes a brief history of hurricane occurrences in New England, a description and summary of experienced losses in recent hurricanes, and a discussion of several methods of reducing damages.

5. NAVIGATION REPORTS

The Pawcatuck River and Little Narragansett Bay have been the subject of many published and unpublished reports since 1871. The following reports form the basis for the existing navigation project:

a. House Document No. 62, 54th Congress, First Session; authorized June 3, 1896.

b. Specified in Act, March 3, 1905.

c. House Document No. 49, 71st Congress, Second Session, 1929.

d. House Document No. 839, 76th Congress, Third Session; authorized March 2, 1945.

DESCRIPTION

6. LOCATION AND EXTENT OF AREA

Pawcatuck is located in the Town of Stonington, New London County, Connecticut, on the west bank of the Pawcatuck River which is a common boundary line for the States of Rhode Island and Connecticut. It is approximately 15 miles east of New London, Connecticut, and about 45 miles west of Newport, Rhode Island at the mouth of Narragansett Bay. Westerly, Rhode Island is located across the river from Pawcatuck on the east bank of the Pawcatuck River. The area of study is the tidal reach of the Pawcatuck River and Little Narragansett Bay, which is the mouth of the river. The principal industrial area of Pawcatuck is about 5 miles upstream from the mouth of the Pawcatuck River, placing it in the area of tidal flooding and inundation from the Atlantic Ocean.

7. PAWCATUCK RIVER

The Pawcatuck River rises in Worden Pond in the western part of South Kingstown, Rhode Island, and follows a meandering course, first generally west about 25 miles and then south about 8 miles, to its mouth at Little Narragansett Bay, an arm of Fishers Island Sound which in turn is an arm of the Atlantic Ocean. The river has a total fall of approximately 90 feet from its headwaters to the sea. It is tidal and navigable to Westerly, Rhode Island, a distance of about five miles. The lower ten miles of the river forms a common boundary between the States of Connecticut and Rhode Island. Drainage area at the mouth of the river is 303 square miles.

8. TIDES

The mean tidal range is 2.5 feet at the mouth of the Pawcatuck River. Spring tides have an average range of [illegible] feet and a maximum range of about 5.0 feet. The time interval for a complete tidal cycle averages about 12 hours and 25 minutes. This results in the daily occurrence of two low and two high waters on an average of six out of every seven days. The U. S. Geological Survey river gaging station, located about six miles from the mouth of the river or about one mile above Pawcatuck, indicates that only the high tide of the cycle affects the water surface at the gage during low flow conditions.

9. GEOLOGY

Pawcatuck, Connecticut, lies on the seaboard lowland of the New England physiographic province, on the west bank of the upper tidal portion of the Pawcatuck River. Seaward, the river is navigable with a 10-foot channel and empties 4 miles downstream into Little Narragansett Bay, at the juncture of Fishers Island Sound and Block Island Sound. A prominent glacial till headland, Watch Hill, Rhode Island, provides great protection from storm waves. The headland is part of a glacial terminal moraine, the Harbor Hill moraine, which runs along the entire Rhode Island coast west of Narragansett Bay, departs seaward at Watch Hill, appears in the form of Fishers Island, submerges again, and reappears to form the northern backbone of Long Island. It is responsible for the existence of the Pawcatuck River, because the resistant and impervious moraine serves as a giant dam, preventing normal direct seaward drainage from the entire coastal area of western Rhode Island, resulting in drainage diverted to the west through Pawcatuck.

10. AREA MAPS

The area under study appears on standard quadrangle sheets of the U. S. Geological Survey, at scales of 1:62,500 and 1:31,680, and on a general map of the States of Massachusetts, Rhode Island, and Connecticut, at a scale of 1:500,000, which has been published by the Geological Survey. The Army Map Service has issued a series of topographic maps of which one, entitled Providence (NK 19-7), covers the entire watershed at a scale of 1:250,000. Another series covers the entire area of the basin at a scale of 1:25,000. The watershed is also shown on the Rhode Island and Connecticut Transportation Maps, scale 1:250,000, issued by the U. S. Public Roads Administration. The coastal area of the basin and the navigable portion of the Pawcatuck River are shown on U. S. Coast and Geodetic Survey Charts Nos. 358 and 1211. A "Geologic Map Index of Massachusetts, Rhode Island and Connecticut," scale

1:500,000, dated 1952, showing areas covered by published geologic maps, has been issued by the U. S. Geological Survey.

ECONOMIC DEVELOPMENT

11. POPULATION

The population of Pawcatuck in 1950, based on U. S. Bureau of the Census figures, was 5,269. This represents a population increase of about 12 percent since 1940. An estimate by the Connecticut Health Department in 1957 indicated the population had increased to about 7,000. This trend is expected to accelerate with the continued development of New London County and the anticipated increase in industry in the Pawcatuck-Westerly area. A recent study made by the University of Connecticut reveals that about 74 percent of the growth since 1950 was attributable to migration and the balance to natural increase.

12. INDUSTRY

Manufacturing has long been the base of the economy of Pawcatuck. There are two large manufacturing establishments in Pawcatuck, although one is inoperative at the present. The other factory manufactures printing presses, accessory machinery, shapers, drills and rocket motors. The inoperative plant produced stapling machines and staples until early in 1957 when operations were transferred to a new plant in Rhode Island. During the approximately ten-year period that the company operated in Pawcatuck, it was estimated that its production increased five fold. The company still maintains the plant, although it is available for rent at present. In 1956, these two companies employed approximately 1,450 people, or about 50 percent of the total number of persons employed in manufacturing in the Town of Stonington. The total annual manufacturing payroll for Stonington in 1956 was in excess of $11,000,000.

13. TERMINAL FACILITIES

A commercial landing dock with a frontage of 500 feet and bulk oil tank storage facilities 500 x 1,000 feet is located on Mechanic Street in Pawcatuck. There are two public landing docks in Pawcatuck, one with a 200-foot frontage. A town dock is located in the Avondale section of Westerly, Rhode Island. The three public wharves in Watch Hill Cove have dockage space of about 350 feet. The Watch Hill Yacht Club has a wharf with dockage space 45 x 100 feet and two floats 12 x 30 feet. The Westerly Yacht Club, located on Watch Hill Road in Westerly, Rhode Island, has four docks varying in length 60-112 feet. No facilities for handling heavy freight exist in Little Narragansett Bay or on

the Pawcatuck River, however, there are a few bulkheads and wharves for commercial use. Storage facilities are available for about 685 boats. A marine engine repair shop is located on one of the lower wharves at Westerly. Five private wharves are in use near the head of navigation. There are no regular water lines of transportation.

14. AGRICULTURE

Agriculture has only a minor roll in the economy of the Town of Stonington, consisting principally of dairying and truck-farming on small holdings. It is of very little importance in the Pawcatuck area, especially the areas inundated by hurricane tides.

15. POWER

The survey area is served by the Mystic Power Company, a subsidiary distributing company of the New England Electric system. The transformer station is located in Westerly, Rhode Island, across the river from Pawcatuck.

16. NAVIGATION

Navigation in the Pawcatuck River is confined to Little Narragansett Bay and to the tidal reaches of the River. The tidal portion of the River is navigable to Westerly, Rhode Island, a distance of about five miles. The annual amount of commerce in the Pawcatuck River during the past 10 years (1947-1956) amounted to about 15,000 tons, consisting primarily of petroleum and petroleum products. The vessels presently carrying the commerce are motor vessels with drafts ranging from 3 to 11 feet. There were 114 vessel trips reported in 1952. Seven of the vessels had drafts of 11 feet and nine had drafts of 10 feet. The waters of Little Narragansett Bay and the Pawcatuck River are also used extensively, especially during the summer months, by recreational craft ranging in size from small motor boats to large yachts of 100 feet or more in length and up to seven feet in draft.

17. TRANSPORTATION

The area is served by a network of modern highways and secondary roads. The two principal routes are U. S. No. 1 which passes through Pawcatuck in an east-west direction and connects with Connecticut Routes 2 and 3 which run northeast and northwest from Pawcatuck. The main line of the New York, New Haven and Hartford Railroad from Boston to New York provides daily passenger and freight service for the Pawcatuck-Westerly area, with the station located just across the river in Westerly, Rhode Island. The Trumbull Airport, about 12 miles southwest of Pawcatuck, and the Westerly State Airport, Rhode Island, about one mile southeast of Pawcatuck, accommodate the Pawcatuck area.

18. RECREATION

The Pawcatuck River and Little Narragansett Bay are important recreational areas serving large population centers in Rhode Island, Connecticut, and southern Massachusetts. Fishing, boating and bathing facilities are available along both shores of the river, near the mouth and in the Bay. Striped bass, blackfish, weakfish and flatfish abound in the offshore waters. Numerous yacht clubs and boat yards provide innumerable opportunities for the sailing and motor-boating enthusiasts. Extensive public bathing beaches are located near Watch Hill as well as in Stonington, providing a choice of either ocean surf or quiet, protected salt water swimming. The increasing growth of the tourists demands is resulting in the creation of more and more recreational facilities.

19. POLLUTION

Storm sewer systems are provided within the Pawcatuck Fire District which includes the survey area of Pawcatuck. Sanitary sewage is disposed of by river dilution and private septic systems. The Pawcatuck District has completed plans for a new sewage disposal plant approved by the Connecticut State Water Resources Commission and the State Department of Health.

20. FISHERIES

There is no sport fishing in the immediate harbor area; however, in the area immediately offshore from Little Narragansett Bay can be found winter flounder, summer flounder, scup, butterfish, striped bass, mackerel, cod, tuna, bluefish and weakfish. Both commercial and recreational use is made of these fishery resources. Little Narragansett Bay and the tidal portion of the Pawcatuck River is the source of salt and brackish water fish and shellfish.

CLIMATOLOGY

21. CLIMATE

The Pawcatuck area has a temperate and changeable climate marked by four distinct seasons which are characteristic of its latitude and of New England. Owing to the moderating influence of Long Island Sound and the Atlantic Ocean and particularly to the variable movements of high and low pressure systems approaching from the west or southwest, extremes of either hot or cold weather are rarely of long duration. In the winter, coastal storms frequently bring rainfall, in contrast to snow in the more northerly areas of Connecticut. In the summer, cooling relief from hot, humid weather is provided by sea breezes from the south,

thunderstorms from the west, and cool air from the north. The prevailing winds are northwesterly in the winter and southwesterly in the summer. High winds, heavy rainfall, and abnormally high tides occur with unpredictable frequency. Hurricanes can be expected especially during the months of August, September, and October.

No official climatological records have been maintained at Pawcatuck; however, an official U. S. Weather Bureau station has been maintained at New London, Connecticut, approximately 15 miles west. Appendix B contains detailed information on climatology, based on published records of the U. S. Weather Bureau station at New London, Connecticut.

22. TEMPERATURE

The average annual temperature of the New London area, based on records for the period 1871 to 1954 is approximately 50°F. February, the coldest month, has a mean temperature of 29.8°F, and July, the warmest month, has a mean temperature of 71.7°F. Freezing temperatures, which are common from late November through March, occur on an average of 100 to 120 days a year. The lowest temperature recorded in the New London area was -17°F on 9 February 1934, and the highest temperature was 100°F on 26 August 1948. The monthly mean, maximum and minimum temperatures at the U. S. Weather Bureau Station, New London, are given in Table B-1, Appendix B.

23. PRECIPITATION

The mean annual precipitation over the New London area during the past 84 years (1871-1954) has ranged from a minimum of 30.05 inches in 1896 to a maximum of 60.62 inches in 1919. The mean annual rainfall amounts to about 44.6 inches and is rather evenly distributed throughout the year. Measurable precipitation occurs on an average about 120 to 125 days out of the year, or one day out of three. Average monthly rainfall varies between 4.39 inches for August and 3.09 inches for June. Extremes of monthly precipitation have ranged from 16.44 inches in August 1874 to 0.01 inch in June 1949. Annual snowfall based on 34 years of record averages 33.9 inches. A summary of monthly precipitation data at New London is contained in Table B-2, Appendix B.

RUNOFF AND STREAMFLOW DATA

24. Records of streamflow at three locations in the Pawcatuck River basin have been obtained by the U. S. Geological Survey for various periods of time since December 1939. One of these gages, with a drainage area of 295 square miles, is situated about one mile upstream of Pawcatuck. A summary of peak discharge is contained in Table B-3, Appendix B.

HISTORY OF HURRICANES AND OTHER GREAT STORMS

25. HISTORICAL HURRICANES AND GREAT STORMS

Descriptions of hurricanes and other severe storms affecting southern New England can be found in the earliest records of the Massachusetts Bay Colony. Governor William Bradford's "History of Plymouth Plantation, 1620-1647" describes a violent storm that occurred along the coast of southern New England on 15 August 1635. Another great hurricane, on 3 August 1638, is described by John Winthrop in his "History of New England from 1630 to 1649". Although there is no record to indicate that these two storms affected Long Island Sound or Fishers Island Sound, it is reasonable to assume, on the basis of present knowledge of the nature of the hurricane surge, that these storms caused inundation of lowlands along the coast of Connecticut.

The first reference to a violent storm in Connecticut is contained in John Winthrop's Journal "History of New England 1630-1649". Referring to the storm of 16 March 1639, he wrote, "there was so violent a wind at south-southeast and south as the like was not since we came into this land. It began in the evening and increased till midnight. . . . It tare down fences - people ran out of the houses in the night. . . . There came such a rain withal, as raised the waters at Connecticut 20 feet above their meadows. The Indians near Aquiday being pawpawing in this tempest, the devil came and fetched away 5 of them". Early newspapers and diaries between 1770 and 1900 contain a number of references to severe storms in Connecticut. The four most notable storms during this period are those of 19 August 1788, 23 September 1815, 3 September 1821, and 24 August 1893. Accounts of tidal flooding along the Connecticut coast in severe storms, other than hurricanes, have been recorded since 1767. Tide gage records at a number of localities along the coast of Connecticut are available which indicate the height of tidal flooding experienced during the past 20 years.

26. RECENT HURRICANES AND GREAT STORMS

More numerous records are available of hurricanes and other storms that have caused tidal flooding along the Connecticut coast subsequent to 1900, with good records available for the years since 1930. Among the best known storms during the past 28 years, all of which caused tidal flooding of damaging proportions in the New England area, are the following:

HURRICANES	OTHER STORMS
a. 21 September 1938	a. 25 November 1950
b. 31 August 1954 (Carol)	b. 16 March 1953
c. 14 September 1944	c. 17 October 1955
d. 12 September 1954 (Edna)	

Further data on the history of hurricanes are contained in Appendix A.

27. HURRICANE FREQUENCY

The distribution of recorded hurricane occurrences along the Connecticut coast, by estimated degrees of intensity, is shown in Table 1.

TABLE 1

RECORDED HURRICANE OCCURRENCES
CONNECTICUT COAST

Category	Years 1770-1800	1801-1900	1901-1957	Total
A. Caused severe tidal flooding	1	7	7	15
B. Damage from wind and rainfall (usually accompanied by high seas and moderate tidal flooding)	2	5	8	15
C. Threatened area	1	4	23	28
TOTAL	4	16	38	58

The fact that there is a record of 38 hurricane experiences thus far in the 20th century (1901-1957), as compared with 20 occurrences in the 131-year period between 1770 and 1900, is believed to be due to a lack of records on storm occurrences prior to 1900 rather than a trend toward increased hurricane activity in recent years.

Records indicate that the Connecticut coastal area has experienced severe tidal flooding from hurricanes upon seven occasions since 1900. In addition, storm tides have caused flooding on at least 21 occasions since the first of 1938. An elevation-frequency curve (see Plate B-8, Appendix B) for combined tidal plus fresh water elevations has been prepared for Pawcatuck based on (1) known elevations of tidal flooding at Pawcatuck and the Westerly business center for Hurricane "Carol", August 1954; (2) known elevation of tidal flooding at the Westerly business center for the Hurricane of September 1938; and (3) water-stage data for the period 27 November 1940 to 10 December 1957, as recorded at the U. S. Geological Survey river gaging station located about one mile upstream from Pawcatuck on the east bank of the Pawcatuck River.

With respect to seasonal variation of hurricane occurrences in southern New England, the period of greatest activity extends from early August to the end of October. However, records indicate occurrences as early as the middle of June and as late as the middle of December.

HURRICANE CHARACTERISTICS

28. GENERAL DESCRIPTION

The term "hurricane" is applied to an intense cyclonic storm originating in tropical or subtropical latitudes in the Atlantic Ocean north of the Equator. Accumulation of heat close to the surface of the water provides energy for water vaporization and the movement of masses of moist tropical air. A hurricane is characterized by low barometric pressures, high winds (75 miles per hour or greater), heavy clouds, torrential rain, tremendous waves, and tidal surges.

29. ORIGINS AND TRACKS

Most of the hurricanes that have affected the eastern coast of North America have formed either near the Cape Verde Islands or in the western Caribbean Sea. Cape Verde hurricanes move westerly for a number of days with a forward speed of about 10 miles per hour. Occasionally, they proceed straight to the coast

of Texas, but generally, after reaching the middle Atlantic Ocean, they recurve northerly and then easterly. Frequently they cross the West Indies, sometimes striking the eastern coast of the United States between Key West, Florida, and Cape Cod, Massachusetts. After recurvingthe storms usually increase their forward speed to a rate of 25 to 30 miles per hour and occasionally to a speed of 60 miles per hour. The hurricanes which form in the Caribbean Sea generally move in a northerly direction, travel across Cuba, then strike either the Gulf or the southeastern shores of the United States. The hurricanes that most severely affect New England usually approach from the south-southwest after recurving east of Florida and skirting the Middle Atlantic states. The paths of a number of selected hurricanes are shown on Plate A-1, Appendix A.

30. WINDS AND BAROMETRIC PRESSURE

The highest winds of a hurricane are those within a circular region extending from the edge of the "eye", or calm center, outward for 10 to 15 miles. The diameter of the eye is usually about 15 miles, although the eye of a mature hurricane may frequently be 20 to 30 miles in diameter. Wind movement is not directly toward the low pressure cyclone center or eye of the hurricane but approaches the center in a counter-clockwise spiral. Consequently, the highest wind velocities occur at points to the right of the hurricane's center where the spiral wind movement and the forward motion of the storm are in the same direction. Since destruction by the wind is greatest in the area on the right side of the hurricane, this area is known as the "dangerous semi-circle". A hurricane following a track over New London, Connecticut, west of Pawcatuck, would place Pawcatuck in this "dangerous semi-circle".

Atmospheric pressure falls rapidly as the center of the hurricane approaches and as the velocity of the wind increases. Minimum barometric readings do not always occur in the center of the eye. In some instances, the minimum is reached at the beginning of the calm period, while in others, the minimum is reached at the end of the calm period. Usually the barometric low is about two inches below the normal sea level pressure of 30 inches. However, in several hurricanes, pressures as low as three inches below normal have been recorded. The lowest barometric pressure of record in the United States, 26.35 inches, was recorded at the northern end of Long Key, Florida on 2 September 1935.

31. RAINFALL

Another characteristic of a hurricane is the heavy rainfall that usually accompanies the storm. The rainfall at the edge of the disturbance is light, normally in the form of showers. As the center approaches, the showers increase in frequency and intensity, becoming heavy to excessive near the eye. The heaviest rain usually falls ahead of the eye, driving torrentially from spiral bands of clouds that sometimes produce nearly two inches of rain per hour. For a 24-hour period, amounts approaching 20 inches are not uncommon. In New England, the hurricane of September 1938 caused rainfall of 6 to 8 inches in a one-day period at a number of locations; in the 1954 hurricane, one-day rainfalls of 4 to 5 inches were recorded. The record rainfall in New England, associated with a hurricane, occurred during Hurricane "Diane" (August 1955) when a rainfall of 15.7 inches in 24 hours (total storm rainfall of 19.8 inches in 48 hours) was experienced at Westfield, Massachusetts, about 70 miles northwest of Pawcatuck. This hurricane, however, had lost its typical characteristics - high winds and tidal surge - by the time it reached and stalled over New England.

32. WAVES

Much of the hurricane damage is caused by waves generated by the winds. The ultimate size of the waves depends on the force and duration of the wind and the fetch or distance the wave travels. No waves of any significance are expected to reach Pawcatuck. Any hurricane induced waves that strike the coastline near the mouth of the river would be dissipated by the numerous bends and restrictions of the river channel in the five-mile reach between the mouth and Pawcatuck.

33. TIDAL SURGES

Flooding results from the movement of the storm surge, or rise in water level, onto a shoaling coast or into a bay or inlet. The surge is caused by a combination of hurricane winds and low barometric pressure in a storm having a track and speed of forward movement synchronized with the normal pattern of tidal movement and oscillations of the sea in the open ocean.

Generally the rise of the sea is gradual as the center of the storm approaches but sometimes it comes with great swiftness. The history of terrible storms, revealing many instances of cities and towns flooded, with thousands of lives lost, gives graphic evidence that such rises are not always gradual.

Usually the level of the storm surge is increased by a rising ocean bed and favorable shore contours, factors which similarly affect the astronomical tide in shore locations. The ordinary rise of the tide amounts to only one or two feet in the open ocean while its range is often ten to twelve feet at coastal points. In certain bays and channels the normal rise is 25 to 50 feet above low water. The times of ebb and flow of such tides are of course well known, but the storm surge comes so rarely to any one community that it is seldom anticipated in its fully developed form. A well defined storm surge is not developed unless the slope of the ocean bed and the contour of the coastline are favorable to its rise, in combination with the proper direction of the storm track and speed of movement. Tidal flooding along the Connecticut coast occurs as the storm surge accompanying northward-moving hurricanes, passing west of Pawcatuck, is directed up Long Island Sound from its eastern end. The time lag for the surge to reach the western end of the Sound is approximately three hours.

DESIGN HURRICANE TIDAL FLOOD

34. WIND FIELD AND BAROMETRIC PRESSURE

In New England, the maximum recorded wind velocity in a past hurricane is a gust of 186 m.p.h. at the Blue Hill Observatory, Milton, Massachusetts, in September 1938. The sustained 5-minute velocity at this location, about 80 miles northeast of Pawcatuck, during this same hurricane was 121 m.p.h. At New Haven (about 65 miles west of Pawcatuck) and Hartford, Connecticut, (about 60 miles northwest of Pawcatuck) sustained winds of 38 and 46 m.p.h., respectively, were recorded with gusts of 46 and 59 m.p.h. respectively, in 1938.

During the hurricane of September 1944, the maximum gust in New England was an estimated 109 m.p.h. at Hartford, Connecticut. At New Haven, Connecticut, the recorded maximum gust was 65 m.p.h. and the sustained 5-minute wind was 33 m.p.h.

Peak gusts measured during Hurricane "Carol", 31 August 1954, are 142 m.p.h. at Mount Washington, New Hampshire, about 225 miles northeast of Pawcatuck, and 135 m.p.h. at Block Island, Rhode Island, about 20 miles southeast of Pawcatuck. Gusts of 65 and 64 m.p.h., respectively, were experienced at New Haven and Hartford, Connecticut.

Low atmospheric pressures are characteristic of the "eye" of a hurricane. The minimum in New England was 28.04 inches recorded at Hartford, Connecticut, during the 1938 hurricane. The lowest pressure recorded in New England during the 1944 hurricane was 28.31 inches at Point Judith, Rhode Island, about 20 miles east of Pawcatuck. In Hurricane "Carol", August 1954, a pressure of 28.20 inches was recorded at Storrs, Connecticut, about 40 miles northwest of Pawcatuck. No records of barometric pressures have been obtained at Pawcatuck. Further data on wind velocities and barometric pressures in past hurricanes are included in Appendix B.

35. ASTRONOMICAL TIDE AND TIDAL FLOODING

An important factor in determining the height of flooding from a tidal surge is the stage of the normal tide at the time the hurricane surge arrives at the coast. The surge in the September 1938 hurricane added 9.5 feet to the astronomical tide at the mouth of the Pawcatuck River and caused flooding to an elevation of 10.4 feet, m.s.l. at this location. The hurricane of 31 August 1954 (Carol), with an 8.2-foot surge, caused flooding to an elevation of 9.7 feet, m.s.l. at the mouth of the Pawcatuck River. Hurricane high-water elevations, predicted coincident astronomical tides, and the storm surges in the two major hurricanes to strike this area in recent times, are tabulated in Table 2.

TABLE 2

TIDAL FLOOD DATA
MOUTH OF PAWCATUCK RIVER
NEAR WATCH HILL, RHODE ISLAND

Date	Time of Peak (E.S.T.)	Hurricane High-Water Elevation (feet, m.s.l.)	Coincident Astronomical Tide (feet, m.s.l.)	Hurricane Surge (feet)
21 Sept. 1938	4:20 P.M.	10.4	0.9	9.5
31 Aug. 1954	9:30 A.M.	9.7	1.5	8.2

The duration of tidal flooding, above the elevation of mean high water, was about 6 hours in the hurricane of 31 August 1954. Further data on tidal high water elevations may be found in Appendix B.

Peak flooding at the mouth of the Pawcatuck River in the 1938 hurricane occurred about 1 hour and 50 minutes before a predicted astronomical high tide of 1.7 feet, m.s.l.; and the 1954 hurricane occurred about twenty minutes before a predicted high tide of 1.5

feet, m.s.l. The greatest surge was 9.5 feet in the hurricane of 1938. The surge in the August 1954 hurricane was 1.3 feet less than that of 1938 and the elevation of tidal-flooding in 1954 was only 0.7 foot below the 1938 level due to the high stage of tide at the time of peak flooding. Had the surge in the 1954 hurricane been equal in magnitude to that of the 1938 hurricane, flooding in 1954 would have reached an elevation of 11.0 feet, m.s.l. or 1.3 feet higher than was actually experienced. If these two hurricanes had struck the mouth of the Pawcatuck River coincident with a high spring tide of 2.5 feet, m.s.l., flooding would have been experienced to an elevation of 12.0 feet, m.s.l. in 1938, and 10.7 feet, m.s.l. in 1954; or 1.6 and 1.0 feet higher, respectively.

In determining future tidal-flood levels, one factor to be considered is the rise in mean sea level that is taking place along the New England coast. Continuing investigations being made by the U. S. Coast and Geodetic Survey in regard to changes in sea level indicate that the elevation of mean sea level has risen at a rate of approximately 0.02 foot per year since 1930. (See report by the Council on Wave Research in Proceedings of the First and Second Conferences on Coastal Engineering, 1952). If this trend continues and storms of the magnitude of the 1938 and 1954 hurricanes were to occur at the end of the next 50 years, flood levels would be approximately one foot higher than were actually experienced in these storms. The rising sea level is important in the severity of future hurricane tidal flooding.

36. STORM TRACKS

The hurricane of 21 September 1938 followed a path about 60 miles west of Pawcatuck, thereby placing Pawcatuck in the sector of the strongest and most damaging hurricane winds. The hurricanes of 31 August 1954 and 14 September 1944, with paths located 5 miles west and 15 miles east of Pawcatuck, did not produce severe winds in this area. Due mainly to the relation between the hurricane tracks and the mouth of Long Island Sound, storm surges moving up the Sound were highest in the 1938 hurricane with the 1954 next in magnitude.

37. SELECTION OF DESIGN HURRICANE

In the design of protective works for Pawcatuck, structures must be of sufficient height and strength to withstand the most severe storm tide that can reasonably be expected. A design hurricane for use in determining the required height of protective structures has been established through the cooperation of the U. S. Weather Bureau and the Beach Erosion Board, assisted by personnel of the Agricultural and Mechanical College of Texas.

The basis for the design storm is a transposition of the September 1944 hurricane. This storm, when it was off Cape Hatteras, had the greatest amount of energy of any known hurricane along the Atlantic Coast. However, the 1944 hurricane, when it struck New England, was not nearly so serious along the Rhode Island and Connecticut Coast as either the September 1938 or August 1954 hurricanes because (1) its energy had been partly dissipated over the land north of Cape Hatteras, and (2) it struck near the time of a low tide.

In deriving the design hurricane, the 1944 storm was transposed so that it would be over water between Cape Hatteras and the New England coast, resulting in less rise in barometric pressure at the center of the storm as it moved northward than was actually experienced in 1944. The transposed hurricane, having the intensity of the 1944 hurricane off Cape Hatteras, is assumed to move in a due northerly direction with a forward speed of 40 knots (about 46 miles per hour) in one case, and 30 knots (about 35 miles per hour) in a second case, and to pass over New England with its center 49 nautical miles (56 statute miles) west of Montauk Point, Long Island, near the entrance to Long Island Sound. This change in the track of the storm produces the highest surge along the Connecticut coastline, on the north shore of Long Island Sound.

Characteristics of the transposed 1944 storm are approximately the same as a "Standard Project Hurricane" with respect to the central pressure, the radius of the hurricane, storm speed and wind field.

38. DESIGN FLOOD LEVELS

The September 1938 hurricane surge near the eastern entrance to Long Island Sound at the mouth of the Pawcatuck River near Watch Hill, Rhode Island, has been calculated to be 9.5 feet. The surge for the design hurricane has been determined to be 13.4 feet, or 1.4 times greater than the September 1938 surge. The computations of these storm-tide potentials were performed by the Agricultural and Mechanical College of Texas, under contract with the Beach Erosion Board, in connection with their research program.

The design hurricane tidal surge at Pawcatuck was obtained by adding to the 13.4-foot surge at the mouth, the backwater effect of the river, calculated to be 0.8 feet. This storm-tide potential occurring in conjunction with a high spring tide of 2.5 feet at the mouth of the Pawcatuck River would result in a design stillwater level of 16.7 feet, m.s.l. A detailed discussion of the design storm-tide derivation is contained in Appendix B.

39. DESIGN RAINFALL

Records of precipitation are not available in the immediate vicinity of Pawcatuck that would indicate the intensity or total storm rainfall that has occurred during any of the recent hurricanes or major storms. In the 3-4 November 1927 storm, however, Westerly, Rhode Island (across the river from Pawcatuck) had rainfall of 3.15 inches in 4 hours and 15 minutes plus an additional 5.97 inches in the following 8 hours, or 9.12 inches in about 12 hours. The design rainfall criteria for Pawcatuck was based on data contained in the U. S. Department of Agriculture Publication No. 204, "Rainfall Intensity-Frequency Data", which gave an intensity of about 3.5 inches per hour for the local protection project.

40. DESIGN RUNOFF

Design runoff for the Pawcatuck area was determined from the rainfall intensity as discussed in paragraph 39 above, and was the basis of runoff studies for the Pawcatuck area. It was determined that the peak runoff from the area would be 68 c.f.s. In addition, it was estimated that 10 c.f.s. would be contributed from the residential area west of the New York, New Haven and Hartford Railroad.

EXTENT AND CHARACTER OF FLOODED AREA

41. Large areas in Pawcatuck, Connecticut, and Westerly, Rhode Island, are vulnerable to tidal flooding in the 5-mile tidewater reach, at the mouth of the Pawcatuck River and along the adjoining coastal areas fronting on Little Narragansett Bay. Three areas are particularly prone to flooding: (1) the industrial-commercial section of Pawcatuck extending about 0.5 mile downstream from the New York, New Haven and Hartford Railroad bridge, (2) the industrial-commercial section of Westerly extending about 0.5 mile on either side of the railroad bridge, and (3) the Avondale and Watch Hill summer resort sections on Pawcatuck River and Little Narragansett Bay. In the first area, the congested Pawcatuck area near the head of tidewater, nearly 35 dwellings and 50 commercial establishments are susceptible to tidal flooding. This reach includes nearly all of the Pawcatuck commercial establishments and the two largest of the five industrial plants in the village. On the opposite bank, although nearly 60 commercial establishments are subject to tidal flooding in the Westerly urban area, the distribution of these properties is less concentrated. Three industrial firms, employing about 8 percent of Westerly's industrial workers, and approximately one-third of the commercial establishments are exposed to tidal flooding in the Westerly urban area. Nearly one-half of the flood-prone residential and commercial structures in the Avondale-Watch Hill reach are associated with the summer vacation industry. Five

of the six boatyards and yacht clubs in the Pawcatuck River area are located in this Westerly reach and are used primarily for servicing recreational boats based in the numerous coves near the mouth of the river.

HURRICANE TIDAL-FLOOD DAMAGE

42. EXPERIENCED TIDAL-FLOOD LOSSES

Damage surveys conducted in the Pawcatuck River area in late 1956 indicated that damage caused by the tidal flooding which accompanied Hurricane "Carol" on 31 August 1954 amounted to over $1,900,000. Nearly 50 percent of the total loss in the area occurred in two industrial plants in the Mechanic Street section of Pawcatuck. Beach properties along the Westerly side of the Pawcatuck River sustained nearly one-fourth of the total loss in the area. Most of the remaining loss was experienced by residential and commercial properties in the Pawcatuck-Westerly urban concentration near the head of tidewater. Tidal-flood losses are discussed in detail in Appendix C. Distribution of the total loss by towns and by types of damage is shown in Table 3.

Damages sustained by recreational craft afloat and by transient automobiles in the flooded area accounted for losses which were not included in the tabulations of damages, as specific information on these losses was meager. Available information indicates that losses of this nature were substantial in both the 1938 and 1954 hurricanes.

TABLE 3

EXPERIENCED TIDAL-FLOOD LOSSES
HURRICANE "CAROL", 31 AUGUST 1954
PAWCATUCK, CONNECTICUT, AND WESTERLY, RHODE ISLAND

(Losses in $1,000)

Town	Urban	Rural	Industrial	Utility	Highway	Total
Pawcatuck	255	5	820	5	5	1,090
Westerly	750	--	20	25	25	820
	1,005	5	840	30	30	1,910

43. RECURRING TIDAL-FLOOD LOSSES

On the basis of stage-loss data obtained from field investigation of damages, estimates have been made of the recurring losses that would be experienced in future hurricanes at the various stages above and below the 1954 flood level. These losses are summarized in Table 4, below. Additional data on the determination of recurring losses and a breakdown of anticipated recurring losses in the Pawcatuck industrial area are included in Appendix C.

TABLE 4

RECURRING TIDAL-FLOOD LOSSES IN PAWCATUCK RIVER AREA
(1958 Price Level)

Pawcatuck (Stonington), Connecticut and Westerly, Rhode Island

Recurring Hurricane	Flood Stage (feet, m.s.l.)	Recurring Losses
21 Sept. 1938	11.1	$2,600,000
31 Aug. 1954	10.4	1,900,000
14 Sept. 1944	7.6	200,000

44. AVERAGE ANNUAL FLOOD LOSSES

Average annual flood losses in the industrialized Mechanic Street area in Pawcatuck, as determined from damage-frequency relationships, are estimated at $67,000.

45. SCARE COSTS

In addition to tidal-flood losses, significant costs result from the institution of temporary preventive measures following a hurricane warning even though the anticipated hurricane does not cause flooding. Included among such measures are provisions for sandbagging windows and other openings, installation of pumping facilities, and plans for temporary evacuation of space, machinery and other equipment likely to be flooded. It is estimated that "scare costs" to industrial interests in the Mechanic Street section of Pawcatuck will amount to $6,000 in each hurricane scare. Based on a frequency of four warnings every ten years, a frequency consistent with past records in this area and adjacent coastal areas, average annual scare costs for the Mechanic Street industrial area amount to $2,400.

EXISTING CORPS OF ENGINEERS' PROJECTS

46. HURRICANE PROTECTION PROJECT

There is no existing or authorized Corps of Engineers' hurricane protection project for the prevention of hurricane tidal-flood damages in the Pawcatuck area.

47. NAVIGATION PROJECTS

Federal improvement of Pawcatuck River and Harbor in the interest of navigation dates back to 1871. The existing project, adopted in 1896, provides for a channel 10 feet deep and 200 feet wide in Little Narragansett Bay and the River from Stonington to Avondale, thence 100 feet wide to the lower wharves at Westerly; thence 40 feet wide to the upper wharves, length about 7.5 miles; a channel 10 feet deep, 100 feet wide from the mouth of the river into Watch Hill Cove, length about 0.28 mile; an anchorage basin 10 feet deep in Watch Hill Cove; a riprap groin near southwest corner of the basin, about 200 feet long; and removal of obstructions at Watch Hill. The existing project is 71% completed.

HURRICANE PROTECTION IMPROVEMENTS BY OTHERS

48. FEDERAL AND STATE IMPROVEMENTS

No improvements in the interest of minimizing hurricane tidal-flood damages in the Pawcatuck area have been undertaken by any other Federal agencies or by the State of Connecticut.

IMPROVEMENTS DESIRED

49. PROPOSALS BY LOCAL INTERESTS

Officials of Stonington, Connecticut, and Westerly, Rhode Island requested high priority for studies of protection of the heavy damage areas near the Pawcatuck River and proposed two alternative plans of protection:

a. Closing the breach in Sandy Point and raising Sandy Point and Napatree Point above flood level to form a barrier that would protect the Little Narragansett Bay and Pawcatuck River area.

b. Construction of a rock barrier with navigation opening across the Pawcatuck River at Pawcatuck Rock to prevent the tidal surge moving up the river.

Local interests stressed the urgency of protection for their industrial and commercial center as one of the larger manufacturers had moved out of the area in 1958.

50. MEETING WITH LOCAL INTERESTS

During the course of the survey, several meetings were held with representatives of both State and local governments as well as local industrial interests, to inform them of the progress of the survey, and to obtain their views on the various plans of protection being considered. They insisted that if no economical plan of hurricane protection could be provided for the area as a whole, that every consideration be given to protecting the industrial area on the west bank of the Pawcatuck River.

51. PUBLIC HEARING

A public hearing was held in Stonington, Connecticut on 20 February 1958, to acquaint local interests with the results of the survey and to determine their views and opinion on a plan of local protection for the industrial area on the west bank of the Pawcatuck River. The meeting was attended by about 50 persons including State and local officials, representatives of local industrial and commercial interests, and home owners. At this meeting, local interests restated their need for protection and expressed unanimous approval of the plan of local protection for the Pawcatuck industrial area. State and local interests indicated a willingness to share in the cost of the project.

TIDAL-FLOOD PROBLEM AND SOLUTIONS CONSIDERED

52. TIDAL-FLOOD DAMAGES

Hurricane damages result chiefly from (1) salt-water flooding by the hurricane surge, (2) action of storm-driven waves, (3) fresh-water flooding resulting from torrential rains, and (4) effect of high-velocity winds. This report involves mainly the damages arising from salt-water tidal flooding. Damages from wave action occur in the more exposed coastal areas and are minor in the Pawcatuck River. Fresh-water runoff and flood damages are of secondary importance in the Pawcatuck areas that are subject to tidal flooding. Wind damages are not included in this study.

Damages caused by hurricanes and other great storms may take many forms, including loss of life and property, hazards to health, disruption of normal economic activities, costs of evacuation and reoccupation, and abandonment of industrial and commercial

activities in the area. Some types of damage cannot be prevented, although they may be relieved by careful planning. Damages resulting from tidal flooding of coastal areas or estuaries and fresh-water flooding of river valleys can be significantly reduced in some cases by adequate protective structures.

53. HURRICANE FLOOD PROBLEM

The engineering problem of hurricane tidal flood protection in the Pawcatuck area resolves itself into one of providing protection for as much of the flood area as is economically feasible and practicable. Flooding in this area is caused by the hurricane surge which comes over the top of the barrier beaches (Napatree Beach and Sandy Point), flows through the navigation passage near Stonington, and through the breach in Sandy Point opened by the 1938 hurricane. The surge rises in Little Narragansett Bay and flows up the Pawcatuck River to the concentrated damage areas. The damages have been caused by salt water brought in from the sea by hurricane-induced tidal surges and other great storms. Fresh-water flooding from 295 square miles of watershed has not in the past caused major flood damage at Pawcatuck, but has increased flood levels during periods of salt-water flooding.

In the Pawcatuck River and Little Narragansett Bay area of Westerly, Rhode Island, and Stonington, Connecticut, damages of more than $1,900,000 were sustained from Hurricane "Carol", 31 August 1954. A major part of these damages, nearly 50 percent, were experienced by industry about five miles up the river on the Connecticut bank. Except for this concentration, the damages were widely dispersed on the banks of the river and along the shoreline of Little Narragansett Bay.

54. DEGREE OF PROTECTION REQUIRED

The degree of required protection is indicated by the fact that the area experienced tidal flooding to an elevation of 11.1 feet above mean sea level in the hurricane of 21 September 1938, and to an elevation of 10.4 feet above mean sea level in Hurricane "Carol", 31 August 1954. Some of the industrial buildings were inundated to depths ranging to 5.8 feet above the first floor level. In the event of a Standard Project Hurricane occurring coincident with the peak of a high spring tide, the waters of the lower reaches of the Pawcatuck River would rise to an estimated height of 16.7 feet above mean sea level, and 5.6 feet above the 1938 flood level.

55. PROTECTIVE MEASURES CONSIDERED

Protective measures fall into the following classifications: (a) hurricane warning and emergency flood mobilization measures, including plans for evacuation; (b) revision of zoning regulations and building codes; and (c) protective structures such as dikes, walls, breakwaters, bulkheads and local tidal barriers designed to protect individual portions of the shorefront subject to tidal flooding. These measures are described below:

a. Hurricane warning and emergency flood mobilization measures. A hurricane warning system, combined with emergency mobilization and plans for evacuation, would materially aid in preventing loss of life and property. Such a system, however, would not alleviate the problem of physical inundation of properties. Considerable time is required for emergency precautionary measures, such as boarding up and sandbagging windows, evacuating low-lying areas, removing goods and equipment to higher levels, pulling small craft ashore, and driving vehicles to high ground. A warning system, no matter how extensive and elaborate, might not always provide sufficient time for adequate precautions. The hurricane of 1938, for example, which was at one time reported stalled off Cape Hatteras, swept north to the New England coast, almost unannounced, only eight hours later.

Hurricane alerts and near misses, that result in "scares" only, interfere with the normal activities of the affected residents and in many cases may cause economic loss. It is reported that a single hurricane "scare" incurs costs of $6,000 in Pawcatuck. The hurricane warning services now provided by the U. S. Weather Bureau are necessary, however, to supplement any plan of protection for the Pawcatuck area.

b. Revision of zoning regulations and building codes. The consideration of warnings and emergency measures leads to thought of more permanent relocation of goods and equipment to higher floor levels, relocation out of the flood area entirely, or of more substantial construction to resist the destructive forces of high water and waves. State and local governments, in some instances, have proposed adoption of zoning restrictions to prevent new construction in critical flood areas and revisions of building codes to require sturdier construction in areas where buildings have been demolished by storm tides. Such measures, where proposed for existing concentrations of homes, commercial establishments, and industries, tend to meet with strong opposition because of the high investment in property and the prospective loss to property owners and municipalities. The responsibility for enacting legislation on zoning and building regulations lies with the State and municipalities concerned.

c. Protective structures. Although hurricane warnings, mobilization measures, and revised zoning regulations and building codes will abate the danger of flood damages, they will not eliminate the inherent danger from tidal flooding. The most positive means of protection is by construction that will physically reduce or prevent the inundation of properties by tidal-flood waters that enter the Pawcatuck River at the time of a hurricane. Considered structures include barriers which would completely or partially close off the waterway to the entry of hurricane tides; dikes or walls along the shore which would hold back the high water and give local protection; or a combination of barriers, dikes, and walls. The construction of breakwaters would effect a reduction in hurricane wave heights in more exposed areas. Wave damage, however, is a negligible factor in the damage at Pawcatuck.

56. PLANS CONSIDERED

Consideration has been given to several plans of protection throughout the Pawcatuck-Little Narragansett Bay area, as follows:

a. Use of Natural Barrier Beaches. Hurricane protection by this plan would consist of a barrier-dike system, approximately four miles in length, extending from Watch Hill along Napatree Point and Sandy Point to Stonington. Consideration was given to both gated and ungated navigation openings at the navigation channel north of Sandy Point. This plan would give general protection to the whole of Little Narragansett Bay and the navigable reaches of the Pawcatuck River.

b. River Crossings. Sites for barriers, crossing the Pawcatuck River, were investigated at Pawcatuck Rock and at several alternative locations along the river south of the town. Plans studied varied in respect to methods of providing navigation openings through the barriers, and in methods for the prevention of fresh water ponding behind the barriers. Ponding would be controlled either by a large pumping station or by a diversion channel west of Pawcatuck. These plans would provide protection for much of the Pawcatuck-Westerly area.

c. Local Protection. Local protection by dikes or walls was investigated for concentrated damage areas in Pawcatuck and Westerly.

57. SELECTION OF PLAN OF PROTECTION

The following points were taken into account in eliminating a number of plans for general protection early in the survey and

arriving at the selection of the Pawcatuck local protection plan for further study.

a. The general protection of Little Narragansett Bay would involve a barrier along Napatree Beach and Sandy Point. The extensive length of such a system would mean a high construction cost. In addition, hydraulic studies indicate that the barrier would require a large navigation opening in order to avoid excessive tidal currents under normal conditions. It was determined that, because of the high cost of such a barrier and navigation gate, the utilization of the barrier beaches for the general protection of Little Narragansett Bay would not be economical or feasible.

b. Barriers across the Pawcatuck River in the vicinity of Pawcatuck Rock to give complete protection to the estuary above the barrier were investigated at some length. Due to the lack of storage area, ponding would occur behind such a barrier, causing fresh water flooding from 300 square miles of drainage area. A pumping station with sufficient capacity to pass the storm water runoff of the river basin, would be prohibitive in cost. A diversion plan, to bypass the storm water runoff of the river past Pawcatuck, was also eliminated by its high cost. Hydraulic studies showed that a gated opening would be required in a barrier crossing the river because the ponding area is small.

c. Utilization of barrier beaches and river crossings alike were determined to be more costly than the benefits would justify. Thus no general or over-all protection plan of the area proved to be feasible.

d. Local protection of small areas characterized by a concentration of experienced flood damages emerged as the only answer to the problem. This eliminated all consideration of navigation gates and large pumping stations for river flow, although pumping on a smaller scale for local drainage might still be necessary.

e. An examination of possibilities for local protection projects disclosed that the industrial section in Pawcatuck suffered the heaviest concentration of damages from recent hurricanes of record, nearly 50 percent of the total. This area appeared to lend itself to a simple and practicable means of protection.

58. The analyses of various alternate plans indicated that local protection of the industrial section of Pawcatuck is the most promising project in the survey area.

59. PAWCATUCK LOCAL PROTECTION PLAN

The Pawcatuck local protection project is shown on Plate 2 of this report. The main feature of the plan is a dike and land wall system extending about 2,000 feet along the west bank of the Pawcatuck River. More detailed material is contained in Appendix E.

This protection consists of 2,386 linear feet of earth-fill dike, 208 linear feet of concrete wall and a pumping station. The dike would be rock faced on the top and river slope, with a gravel blanket on the landward slope. The protection begins at high ground south of the Cottrell plant, extends along the water front to the north boundary of the Bostitch plant and then ties into the railroad embankment west of Mechanic Street. The dike portion would have a top elevation of 17.0 feet above mean sea level, a top width of 10 feet, and side slopes of 1 on 2 both sides. The wall forming the northern end of the protective works would have a top elevation of 17.0 feet above mean sea level.

Appurtenant structures consist of a 40,000 g.p.m. pumping station located on the grounds of the Cottrell plant and two stop-log structures, crossing Mechanic Street, one located at the railroad underpass south of the Cottrell plant and the other in the protective alignment north of the Bostitch plant.

60. DRAINAGE MODIFICATIONS

Construction of the proposed plan of protection would cross many of the existing drains and sewers, throughout the area behind the protective works, thus necessitating the construction of an interceptor sewer along the toe of the dike. The interceptor would carry all sewage, interior runoff and industrial wastes to an inlet chamber in the pumping station. At this point the flow would be directed, by means of sluice gates, to pass through the pumping station during times of flooding and through a 48 inch outfall directly to the river during normal conditions.

61. LANDS, RIGHTS-OF-WAY AND RELOCATIONS

Construction of the project would require the acquisition in fee of about 2.7 acres of land and a temporary construction easement on one acre of land. Land within easement areas not actually occupied by protective structures and all permanent access roads would be available for use by the owner.

62. HYDROLOGIC AND HYDRAULIC CONSIDERATIONS

The design of the Pawcatuck local protection project was based on the following:

a. A design stillwater level of 16.7 feet above mean sea level, derived from tidal surge determination predicated on wind fields and barometric pressures of a hurricane on a northerly track passing 49 nautical miles west of Montauk Point with the peak of the surge coincident with a high spring tide plus allowance for a differential in the water level at the coastline and the level upstream at the project.

b. A maximum rainfall intensity of approximately 3.5 inches per hour over the 39-acre project area, based on the U. S. Department of Agriculture Rainfall Intensity - Frequency Data.

c. Design runoff, obtained from the Rational Formula ($Q=CI\bar{A}$), with a peak of 68 c.f.s. from the protected area plus an estimated 10 c.f.s. from the area above the New York, New Haven and Hartford Railroad embankment.

d. A pumping station with a capacity of 89 c.f.s. (40,000 g.p.m.).

63. DEGREE OF PROTECTION

The Pawcatuck local protection project would afford complete tidal-flood protection to about 31 acres of property in Pawcatuck below an elevation of 16.7 feet, m.s.l. This represents protection to an area in which nearly 50 percent of the total flood damages were sustained although geographically it covers about 2 percent of the entire flooded area.

64. EFFECT OF PLAN ON HARBOR INTERESTS

The effects of the Pawcatuck local protection project on the various interests concerned with the use of the river and waterfront areas at Pawcatuck are discussed in the following paragraphs:

a. Navigation. The selected plan of protection will have no effect on the range of tide, nor will there be any reduction in the depth of water available for navigation.

b. Pollution. Federal and State health authorities have considered the effect of the protective system on pollution in the Pawcatuck River. They have concluded that the plan will not adversely affect sanitary conditions in the river.

c. Fish and Wildlife. Federal and State fish and wildlife interests have concurred in the opinion that the selected plan of protection will not be detrimental to the fishing resources of the area.

d. Recreation. The selected plan of protection will have no adverse effect on the present recreational activities of the area.

e. Industry. The plan will not require the removal of any commercial or industrial buildings or cause curtailment of present industrial activities. Much of the project benefits would accrue to industry.

65. EFFECT OF PLAN ON ADJACENT SHORELINE

The dikes in the selected plan of hurricane protection for Pawcatuck will not cause accretion or erosion along the adjacent shoreline.

ESTIMATES OF FIRST COSTS

66. All estimates have been prepared on the basis of 1958 price levels, using unit prices based on actual bid prices of similar work in the region. The estimated total first cost is $595,000, which includes allowances for engineering and design and for supervision and inspection during construction. Table 5 summarizes the principal items of first cost with detailed costs given in Appendix E. The figures in the tabulation are based on local interests contributing 30 percent of the first cost of the project, exclusive of preauthorization survey costs, presently estimated at $10,000. The contribution to the first costs comprises (1) a cash contribution presently estimated at $86,000, and (2) furnishing all required lands, easements, rights-of-way and relocations, presently estimated at $90,000.

ESTIMATES OF ANNUAL CHARGES

67. Total annual charges amount to $27,000, and include interest at a rate of 2.5 percent, amortization over a 50-year project life, and an allowance of $5,800 for annual operation and maintenance, which includes a charge to cover the cost of major replacements during the estimated life of the project. Local interests would be required to maintain and operate the project.

TABLE 5

FIRST COSTS AND ANNUAL CHARGES
(1958 Price Level)
PAWCATUCK LOCAL PROTECTION PLAN
PAWCATUCK, CONNECTICUT

Item	Federal	Local	Total
	First Cost and Investment		
Construction of Dike, Land Wall and Pumping Station	$419,000(1)	$86,000(2)	$505,000(1)
Relocation of Gas and Water Utilities	--	10,000	10,000
Lands and Damages	--	80,000	80,000
Total First Cost	$419,000	$176,000	$595,000
Interest during construction	5,000	2,000	7,000
Total Investment	$424,000	$178,000	$602,000
	ANNUAL CHARGES		
Interest on Investment	$ 11,000	$ 4,000	$ 15,000
Amortization	4,000	2,000	6,000
Maintenance and Operation	--	5,800(3)	5,800(3)
Estimated Tax Losses	--	200	200
Total Annual Charges	$ 15,000	$ 12,000	$ 27,000

(1) Includes cost of preauthorization survey studies, presently estimated at $10,000.
(2) Represents a local cash contribution, presently estimated at $86,000, to the United States. This amount, when added to the estimated cost of $90,000 for lands, easements, rights-of-way and relocations necessary for the construction of the project, represents a local interests share of 30 percent of the first cost of the project, less the cost of preauthorization survey studies.
(3) Includes estimated cost of major replacements.

ESTIMATES OF BENEFITS

68. TANGIBLE BENEFITS

Evaluated benefits for the Pawcatuck local protection plan include average annual flood damages prevented by the plan and benefits from the elimination of scare costs in the protected area. Total average annual flood damage prevention benefits are estimated at $55,000, at 1958 prices. Approximately 3 percent of this amount could be credited to fresh-water flood prevention benefits. This amount equals the difference between the average annual losses in the Pawcatuck industrial area before protection and the residual average annual losses after addition of protective works.

Average annual benefits from the elimination of scare costs amount to $2,400. Thus the total average annual benefits accruing to the plan are $57,400.

69. UNEVALUATED TANGIBLE BENEFITS

In view of the small area encompassed by the protection plan and the high degree of industrial and residential development within the area, no significant enhancement benefits are anticipated in the protected area. Since the 1954 flood, the Bostitch Corporation, the more northerly of the two large industrial firms in the protected area, has moved to a larger plant outside the Pawcatuck area. It is anticipated that their well designed, up-to-date Pawcatuck plant will be reoccupied by industrial tenants irrespective of protective works. As the primary factor influencing relocation of the Bostitch firm in 1957 was the need for additional space, rather than an endeavor to avoid flood costs, the benefits accruing from protection of their Pawcatuck plant have been computed as flood damage prevention benefits based on the normal industrial reoccupancy of the plant.

70. INTANGIBLE BENEFITS

Construction of adequate protective works in the Mechanic Street section of Pawcatuck would greatly reduce the threat to life and the danger of disease from polluted flood waters in this industrial-residential area. Insecurity and worry among the residents concerning unpredictable hurricane flooding would be virtually eliminated.

ECONOMIC JUSTIFICATION

71. BENEFIT-COST COMPARISON

A comparison of annual charges of $27,000 with annual benefits of $57,400 determined from damage-frequency relationships, gives a benefit-cost ratio of 2.1 to 1.0 for the selected plan of protection. The prevention of damage in one recurrence of a great hurricane would alone be more than sufficient to economically justify the construction of the project.

PROPOSED LOCAL COOPERATION

72. The hurricane protection plan considered for Pawcatuck, Town of Stonington, Connecticut, is a project for local protection against hurricane-induced tidal flooding. On this basis, local interests would be required to participate as follows:

a. Contribute 30 percent of the first cost of the project (not including the cost of preauthorization survey studies) as follows:

(1) Make a cash contribution presently estimated at $86,000.

(2) Provide without cost to the United States all lands, easements, rights-of-way and relocations necessary for construction of the project, presently estimated at $90,000.

b. Hold and save the United States free from damages due to the construction works.

c. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army.

At the public hearing held 20 February 1958, local interests voiced a willingness to participate in project costs, as well as maintenance and operation, in accordance with policies governing flood control projects. Subsequent to the hearing, statements on willingness to comply with a(2), b and c of the above provisions of local cooperation have been received from the Governor of Connecticut and responsible elected officials of the State of Connecticut and Town of Stonington. The Town of Stonington has expressed an ability and willingness to participate with the State in compliance with a(1) above. The State has indicated probable cooperation in the contribution required of local interests, although the extent of the contribution by the State is dependent on the outcome of the January 1959 session of the State legislature. See Appendix F for more detailed information on the hearing.

APPORTIONMENT OF COSTS AMONG INTERESTS

73. A breakdown of the total first cost and annual charges for the Pawcatuck local protection project, between Federal and non-Federal interests, is shown in Table 5. The figures in this table are predicated on local cooperation to the extent set forth in paragraphs 66 and 72, above, with local interests making a cash contribution to the first cost of the project.

The total first cost of the project is estimated at $595,000. The first cost to local interests is presently estimated at $176,000, including $80,000 for the acquisition of lands and rights-of-way and a cash contribution of $86,000. The Federal first cost is presently estimated at $419,000 including $10,000 for pre-authorization survey studies.

The total annual charges for the project are estimated at $27,000. The Federal portion is $15,000 and the local share $12,000 or about 44 percent of the total.

COORDINATION WITH OTHER AGENCIES

74. In the course of this survey, assistance and cooperation have been received from Federal, State, and local agencies that are concerned with hurricane activities, or are particularly interested in the hurricane protection problem in Pawcatuck. Meetings have been held with representatives of these agencies for the purposes of discussing the proposed plan of protection and alternative plans, determining the effect of the plan on other interests concerned with development and use of the water and other natural resources of the locality. These meetings have also developed the relationship between the proposed hurricane protection plan and the plans of other agencies for improvements within the survey area.

a. Federal agencies. The U. S. Weather Bureau of the Department of Commerce has furnished information on the behavior and characteristics of past hurricanes and data on maximum wind velocities and durations that may be expected in future storms.

The Fish and Wildlife Service of the U. S. Department of the Interior, and the Public Health Service of the U. S. Department of Health, Education and Welfare have considered the dike and land wall plan and state that it would have no adverse effect on fishing resources and sanitary conditions in the area.

b. State agencies. The effect of the proposed dike and land wall on pollution has been discussed with the Connecticut State Water Resources Commission. This commission concurs in the opinion that the hurricane protection plan will have no adverse effect on

sanitary conditions in the area. Coordination also has been maintained with the Commission with a view to determining the needs of navigation and correlating the plan of protection with these needs. The Connecticut State Board of Fisheries and Game has considered the barrier plan and state that it would have no adverse effect on the fishing resources of the area.

c. Local agencies. Informal meetings and conferences have been held with municipal officials of Pawcatuck and representatives of industrial interests to obtain their views and comments on the proposed plan and other plans that have been given consideration and to keep local interests advised of the progress being made on the survey.

DISCUSSION

75. THE PROBLEM

The Pawcatuck River and Little Narragansett Bay areas have experienced heavy losses of life and property; over 100 people were drowned in the 1938 hurricane and over 250 homes and buildings swept away. The buildings were not rebuilt on the Napatree Point outer barrier beach. In future hurricanes flood losses are likely to be less in amount and distributed over wide areas except at Pawcatuck, Connecticut where $1,290,000, about 50% of the total estimated damage for a recurring 1938 hurricane, would be concentrated in a small industrial and residential area, five miles up the Pawcatuck River. A design hurricane representative of future potential attacks, derived by transposing the 1944 hurricane, a storm of unusual energy off Cape Hatteras, to a track over water and timed to cause the surge to strike coincident with a spring tide, is capable of causing tidal flooding approximately six feet higher than the 1954 hurricane at Pawcatuck. Protection of this area is needed to sustain the economy and normal employment in the area.

76. ALTERNATIVE SOLUTIONS

Some reduction in hurricane tidal-flood damages could be effected in the Pawcatuck-Little Narragansett Bay area by the institution of improved forecasting and warning services, the establishment of programs for the evacuation of danger areas, the enactment of revised zoning ordinances, and the adoption of modified building codes. Improved warning facilities and plans for evacuation would be desirable for the whole area, as effective in reducing the loss of life and damage to items which are readily movable. However, such emergency measures do not prevent the actual flooding of properties and would therefore be of limited value in preventing damage, particularly in the industrial area of Pawcatuck. The costs incurred by relocation of buildings and rezoning of areas subject to tidal flooding would be prohibitive

in this highly developed area. The valuation of property involved is many times the cost of protection or the amount of damages. Moreover, any extensive relocation would disrupt the entire economy of the area. A positive means of protection which will eliminate the threat of future flooding to existing properties is desirable, particularly in the Pawcatuck industrial section.

77. SELECTION OF PLAN

Plans of protection were considered for the whole Pawcatuck-Little Narragansett Bay area by raising the outer barrier beaches but they proved too costly. Intermediate plans consisting of barriers across the Pawcatuck River, proved to be impractical because of the large fresh-water flow from the 300 square mile Pawcatuck River watershed. Local protection was considered for several areas but the only plan found to be practical and economically feasible is local protection for the principal industrial area of Pawcatuck. Although this plan would provide protection for approximately 2 percent of the flooded area it would prevent about 50 percent of the losses. The plan provides for a dike and land wall system tying into high ground north and south of the industrial properties, and would afford complete protection from flooding for two large industrial plants and 27 residences. These works, with a top elevation at 17.0 feet, m.s.l. are designed to afford protection to a stillwater flood level of 16.7 feet, m.s.l. This design flood level is 5.6 feet above the elevation of flooding experienced in the record hurricane of September 1938.

78. EFFECTS ON OTHER INTERESTS

The proposed project would have no adverse effects on pollution or on fish and wildlife. Construction of the dike would not change the tidal range, or affect navigation in the Pawcatuck River.

79. COSTS

The first cost of the project, including lands, rights-of-way and relocations is estimated at $595,000. The annual charges are estimated at $27,000.

80. BENEFITS

The average annual benefits to be obtained from the protection provided by the Pawcatuck local protection project are estimated to be $57,400. This includes $55,000 derived from the elimination of flood damages, and $2,400 from the elimination of scare costs. The benefit-cost ratio of the project is 2.1 to 1.0.

CONCLUSIONS

81. It is concluded that Pawcatuck, Town of Stonington, Connecticut has sustained heavy damages in the past due to flooding caused by hurricanes and other great storms; and that this area faces the continuing threat of similar damages in the future. It is further concluded that protection against tidal flooding can be attained most suitably through the construction of a dike-land wall system at the principal industrial area of Pawcatuck at a first cost of $595,000. This plan, which would afford a high degree of protection, is amply justified, having a benefit-cost ratio of 2.1 to 1.0.

RECOMMENDATIONS

82. It is recommended that a plan of local protection against hurricane floods be authorized for Pawcatuck, Connecticut as described in paragraph 59 of this report, consisting of a dike and accessory works. The presently estimated first cost of the project is $595,000 to be borne jointly by the United States and local interests. The estimated cost to the United States is $419,000.

It is further recommended that the project be authorized subject to the condition that local interests cooperate to the following extent:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project.

b. Hold and save the United States free from damages due to the construction works.

c. Accomplish without cost to the United States all relocations of and modifications to the existing storm-drainage system, and utilities made necessary by reason of construction of the project; the costs incurred to be credited to the required local cash contribution to the project first cost.

d. Operate and maintain all the works after completion in accordance with regulations prescribed by the Secretary of the Army.

e. Contribute in cash an amount, presently estimated at $86,000, equal to 30 percent of the first cost exclusive of cost of preauthorization survey studies, with credit allowed for the costs incurred in fulfilling local cooperation requirements a and c above.

ALDEN K. SIBLEY
Brigadier General, U.S. Army
Division Engineer

Inclosures
1. Plate 1 - General Plan
File No. PAC-1-1000
2. Plate 2 - Protection Plan
File No. PAC-1-1001

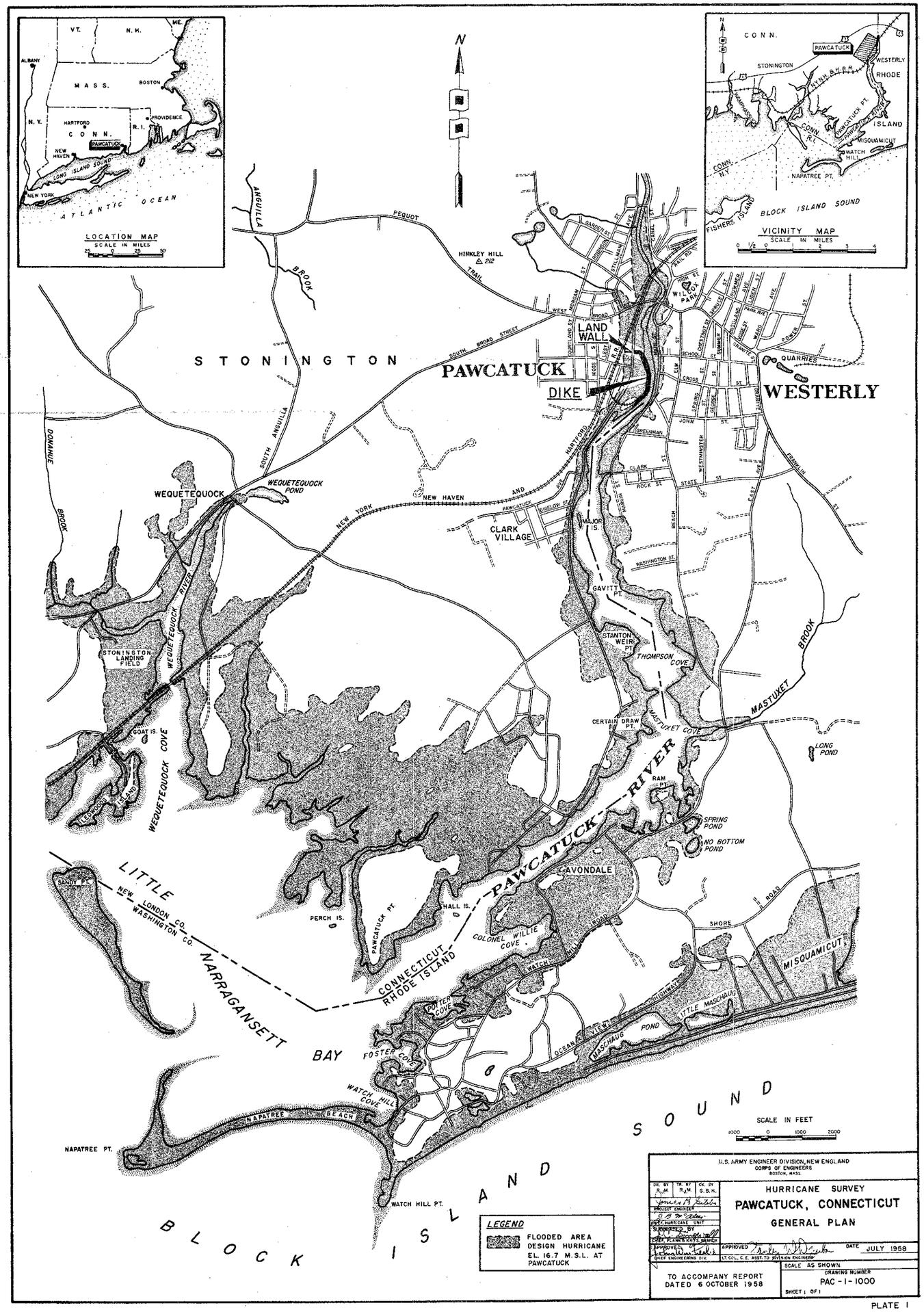
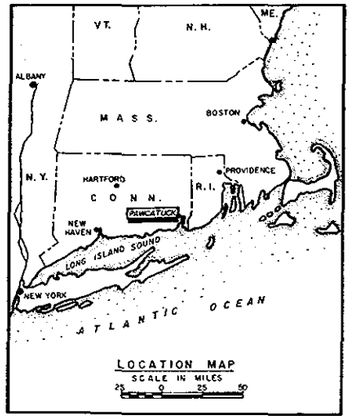
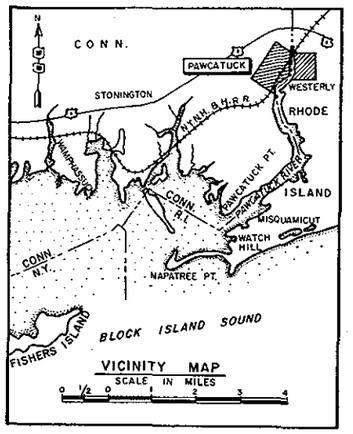

LOCATION MAP
SCALE IN MILES
VICINITY MAP
SCALE IN MILES
STONINGTON
PAWCATUCK
WESTERLY
LAND WALL DIKE
WEQUETEQUOCK
WEQUETEQUOCK POND
CLARK VILLAGE
AVONDALE
MISQUAMICUT
NAPATREE PT.
WATCH HILL PT.
LITTLE NARRAGANSETT BAY
CONNECTICUT RHODE ISLAND
NEW LONDON CO. WASHINGTON CO.
PAWCATUCK RIVER
BLOCK ISLAND SOUND
ATLANTIC OCEAN
LONG ISLAND SOUND
SCALE IN FEET
LEGEND
FLOODED AREA DESIGN HURRICANE EL. 16.7 M.S.L. AT PAWCATUCK
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.
HURRICANE SURVEY
PAWCATUCK, CONNECTICUT
GENERAL PLAN
JULY 1958
SCALE AS SHOWN
TO ACCOMPANY REPORT DATED 6 OCTOBER 1958
PAC - 1 - 1000

PLATE 1

CORPS OF ENGINEERS

U. S. ARMY





U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY	TR BY	CK. BY
R.J.M.	R.J.M.	J.B.G.

PROJECT ENGINEER

CHIEF, HURRICANE UNIT

SUPERVISED BY

CHIEF, PLANS & SPECS. BRANCH

APPROVED

CHIEF ENGINEERING DIV.

HURRICANE SURVEY
PAWCATUCK, CONN.
LOCAL PROTECTION
GENERAL PLAN

APPROVED

DATE JULY 1958

LT.COL., C.E. ASST. TO DIVISION ENGINEER

TO ACCOMPANY REPORT
DATED 6 OCTOBER 1958

SCALE AS SHOWN

DRAWING NUMBER
PAC-1-1001

SHEET

PLATE 2 & E-1

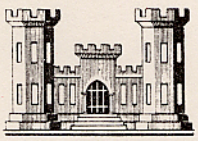
HURRICANE SURVEY

INTERIM REPORT

PAWCATUCK

CONNECTICUT

APPENDICES



U.S. Army Engineer Division, New England
Corps of Engineers
Boston, Mass.

6 OCTOBER 1958

ARMY-NED BOSTON

TABLE OF CONTENTS

TABLES

PLATES

APPENDIX A

HISTORY OF HURRICANE AND OTHER STORM OCCURRENCES

APPENDIX A

HISTORY OF HURRICANE AND OTHER STORM OCCURRENCES

A-1. GENERAL

In order to determine the possibility of future hurricane occurrences, a review has been made of historical data on hurricanes that have struck or threatened the coast of Connecticut. A review of historical records and newspaper files indicates that a number of hurricanes and cyclonic storms have reached the coast of southern New England with devastating force, while numerous other storms have passed so close that a slight change in meteorologic conditions could have resulted in severe damage. Since the eastern entrance of Long Island Sound lies in the path of hurricanes moving into New England from the south, the Connecticut shoreline, on the north of the Sound, has frequently been subject to tidal flooding from hurricane surges moving west up the Sound. The records indicate that from 1770 to present the Connecticut coast has experienced or has been threatened by hurricane tidal flooding upon 58 occasions. About 28 of these hurricanes, passing some distance away, did not cause tidal flooding along the Connecticut coast, however, they did present a potential threat of such flooding. Apparently 30 hurricanes caused significant tidal flooding. Existing records indicate that the five hurricanes which have created the most severe tidal flooding along the Connecticut coast are as follows, chronologically:

15 September 1815
24 August 1893
21 September 1938
14 September 1944
31 August 1954

The earliest hurricanes recorded in New England are known to have affected the coastal areas of Massachusetts and Rhode Island. Since there was very little development along the Connecticut shore until after 1638, there are no available records to indicate that these early storms affected Long Island Sound. It is reasonable to assume that they did cause inundation of the coastal lowlands of Connecticut, as the hurricanes of recent years that have caused tidal flooding along the coasts of southern Massachusetts and Rhode Island also caused flooding along the Connecticut coast. The two earliest hurricanes of record in New England, namely those of 15 August 1635 and 3 August 1638, created flood levels apparently higher than the recent floods of 1938 and 1954, and probably the greatest experienced in New England during the past 320 years.

The early hurricanes were not accompanied by so great a loss of life and property due to the lesser degree of development along the Connecticut coast. However, the recurrence of the two earliest hurricanes under present conditions would cause extensive damages, possibly in excess of the damages sustained in September 1938.

In addition to the above hurricanes, there have been 12 other severe storms, not necessarily of tropical origin, that caused considerable damages (see Table A-2).

A-2. SUMMARY OF HURRICANES

A total of 58 hurricanes which are known to have either hit or narrowly missed the Connecticut coast is summarized in Table A-1. These hurricanes have been classified to indicate their magnitude along the Connecticut coast, as follows:

Type "A": Hurricanes causing severe tidal flooding.
Type "B": Hurricanes causing damage from wind and rainfall (usually accompanied by high seas and moderate tidal flooding).
Type "C": Hurricanes threatening the area.

Of the 58 hurricanes, 15 are of type "A", 15 of type "B", and 28 of type "C". Thirty-eight of the listed hurricane experiences have occurred during the period from 1901 to 1956. The fact that there is a record of 38 hurricanes in this 56-year period, as compared with 20 in the 131-year period from 1770 to 1900, is not considered indicative of a greater trend in hurricane activity in recent years but to a lack of records and information on storms prior to 1900.

TABLE A-1

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category (1)	Source of Data	Remarks
1635, Aug. 15	-	(2)(3)	Great tidal surge along coast of R.I. Records do not indicate effect on Connecticut coast.
1638, Aug. 3	-	(3)	Historical account indicates greatest tidal flooding ever experienced along Mass. and R.I. coast. Records do not indicate effect on Conn. coast.
1641, Nov. 12	-	(3)	A great tide along the coast of Mass. Records do not indicate effect on Conn. coast.
1723, Oct. 31	-	(3)	Very high tides in R.I.; considerable damage. Records do not indicate effect on Conn. coast.
1757, June 30	-	(2)	Atlantic coast hurricane, Florida to Boston, Mass. Records do not indicate effect on Conn. coast.
1761, Oct. 24	-	(3)	Very high tides in Narragansett Bay, R.I. Damage from wind and water. Records do not indicate effect on Conn. coast.
1770, Oct. 19-20	A	(3)	A violent storm; immense loss of life and property along the coast. Report of boat damage at New London, Conn.

(Footnotes are at end of Table)

TABLE A-1 (continued)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category (1)	Source of Data	Remarks
1773, Aug. 19	C	(2) (3)	Passed near Boston, Mass. "Abundant showers" in Conn.
1787, Sept. 19	B	(3)	Report of damage at Stamford and Norwalk, Conn.
1788, Aug. 19	B	(2)	Affected western New England; much wind and rain damage in Conn. and western Mass.
1804, Sept. 3-9	C	(2)	Severe storm; passed over Cape Cod, travelling northeast. No account of damage in Conn.
1804, Oct. 9-10	B	(2) (3)	Reports of wind and rain damage
1815, Sept. 22-23	A	(2)(3)(5)	Severe damage along Conn. coast from tidal flooding. Tide 1 ft. higher that 1938 and 2 ft. higher than 1954 at Pawcatuck, Conn.
1821, Sept. 2-3	A	(2) (3)	Wind damage to boats and homes. Tidal flood damage at New London, Conn.

TABLE A-1 (Cont'd)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category (1)	Source of Data	Remarks
1829, July 24	C	(2)(3)	Reported to have been felt in Boston, Mass. No accounts of damage in Conn.
1841, Oct. 4	B	(2)(3)	Violent winds and heavy rain; reports of wind damage at Hartford, Conn.
1854, Sept. 10-11	C	(2)(3)	Severe in southern states; passed over New England, near Boston. Described as "an old fashioned rain-storm."
1866, Oct. 29-30	B	(2)(3)	Reports of wind damage.
1869, Sept. 8	A	(2)(3)	Reports of severe wind damage at Pawcatuck, Conn.; very high tides at Westerly R. I.; and tidal flooding at Mystic, Conn.
1877, Oct. 5	C	(2)(3)	Path was south of Long Island and Nantucket. Accounts of minor damage in Westerly, R. I.
1878, Oct. 23	A	(2)(3)	Reports of wind damage and very high tides along Conn. coast.
1879, Aug. 18	B	(2)	Passed over Cape Cod. Damage from wind and rain along Conn. coast.
1889, Sept. 10	A	(2)(3)	Streets in Stamford flooded by heavy rain. Very high tide at Greenwich, Conn. Minor damage due to waves at Westerly.

TABLE A-1 (continued)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category (1)	Source of Data	Remarks
1893, Aug. 23-24	A	(2)(3)	Wind, rain, and high tide caused damage along Conn. coast.
1893, Aug. 29	A	(3)	Reports of damage from wind and tide along Conn. coast.
1896, Sept. 9-10	B	(2)(3)	Strong winds and heavy rain along Conn. coast.
1901, Sept. 12	C	(2)(4)	Passed south and east of Cape Cod.
1902, June 11-20	C	(2)(3)(4)	Path crossed Buzzards Bay and Cape Cod moving northeast. Strong winds over L.I. Sound.
1902, June 29	C	(2)	Center passed over Conn. and southern R.I. traveling southeast; no account of damage.
1902, Oct. 7-13	C	(2)(3)(4)	Path south of Long Island and Nantucket, moving east. Heavy rain and high wind at New Haven, Conn. but no accounts of any damage along the Conn. coast.
1903, Sept. 16	A	(2)(3)	Storm crossed northeastern Pa., moving northwest. High winds and high water along Conn. coast.

TABLE A-1 (continued)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category(1)	Source of Data	Remarks
1904, Sept. 15	B	(2)(3)	Center passed over northeastern Conn., moving northeast. Reports of rain and wind damage and heavy surf.
1904, Nov. 9-14	B	(2)(4)	Passed south of Nantucket, moving northeast. Reports of wind damage.
1911, Aug. 29-30	C	(2)	Passed south of Cape Cod. No accounts of damage in Connecticut.
1912, Sept. 11-23	C	(2)	Followed easterly path across southern New England.
1916, July 21	C	(2)(4)	Passed over Providence, R.I., heading northeast. Reports of wind and rain damage in Connecticut.
1920, Oct. 1	A	(2)(3)(4)	Storm passed just west of New York, heading north. Reports of damage from high tides along Conn. coast.
1923, Oct. 14-19	C	(2)(4)	Passed near Boston, moving northwest. Storm of slight energy.

TABLE A-1 (continued)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category[1]	Source of Data	Remarks
1924, Aug. 26	B	(2)(3)	Crossed east tip of Cape Cod, moving northeast. Some damage from strong winds.
1929, Oct. 3	A	(2)(4)	Moved northeast, passing over eastern New York and northwestern Vermont. High tides caused damage along Connecticut coast.
1933, Aug. 23-24	A	(2)(3)(4)	Driving rain and high tides along Conn. coast.
1933, Sept. 10-16	C	(2)(3)	Passed south of Cape Cod moving northeast. No reports of damage in Connecticut.
1934, June 4-21	C	(2)	Travelled overland from Louisiana; crossed Long Island and Cape Cod moving northeast.
1934, Sept. 9	B	(2)(4)	Crossed Long Island and central Conn. moving north. Wind damage along Conn. coast.
1936, Sept. 19	B	(2)(3)(4)	Passed south of Nantucket heading northeast. Wind damage along Conn. coast.
1938, Sept. 21	A	(2)(3)(4)	Most damaging storm to strike southern New England. Tidal-flooding along entire Conn. coast. 11.1 ft., m.s.l. at Pawcatuck.

TABLE A-1 (continued)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category[1]	Source of Data	Remarks
1940, Sept. 2-3	C	(2)	Passed south of Nantucket, heading northeast. No accounts of damage in Connecticut.
1940, Sept. 11-18	C	(2)(4)	Followed northeasterly path east of Cape Cod. No accounts of damage.
1943, Oct. 17	C	(2)(4)	Passed east of Cape Cod, moving due north. No accounts of damage.
1944, Aug. 3-4	C	(2)(4)	Moved northeasterly along path south of Long Island and Nantucket. No accounts of damage.
1944, Sept. 14-15	A	(2)(3)	Center passed over Providence, R.I. and south of Boston, Mass. Tidal-flooding along entire Conn. coast; 7.6 feet, m.s.l. at Pawcatuck.
1944, Oct. 21	C	(2)(4)	Path crossed over Nantucket and easterly tip of Cape Cod. No accounts of damage.
1945, June 26	C	(2)(4)	Followed northeasterly path from Florida to Nova Scotia, passing south of Nantucket.

TABLE A-1 (continued)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category[1]	Source of Data	Remarks
1945, Sept. 19	C	(2)(4)	Overland from Florida; passed just west of New York, moving northeast.
1949, Aug. 29	C	(2)(3)(4)	Travelled overland from northern Florida, crossed center of Maine. High winds at Greenwich, Connecticut.
1950, Aug. 20	C	(2)(4)	Passed south of Nantucket, heading generally northeast. Heavy rain at Greenwich, Conn.
1950, Sept. 11	C	(2)(3)	Passed south and east of Nantucket, then headed east. No report of damage in Conn.
1952, Sept. 1 ("Able")	C	(2)	Followed northeasterly track, approximately over New York. Heavy rain and high wind at Greenwich, Conn.
1953, Aug. 15 ("Barbara")	C	(2)(4)	Followed path south of Long Island and Nantucket.
1953, Sept. 7 ("Carol")	C	(2)	Passed east of Cape Cod, heading generally north.

TABLE A-1 (continued)

HISTORICAL HURRICANES

CONNECTICUT COAST

Date of Hurricane	Category (1)	Source of Data	Remarks
1954, Aug. 31 ("Carol")	A	(2)(3)(4)	Second most damaging storm to hit Conn. coast. Crossed east end of Long Island moving north; 10.4 ft., m.s.l. at Pawcatuck.
1954, Sept. 11-12 ("Edna")	B	(2)(3)	Passed over Cape Cod, heading northeast. High seas, minor damage from wind.
1954, Oct. 5-16 ("Hazel")	B	(4)	Moderate to heavy rains in New England. Peak gusts reached gale and whole gale force.
1955, Aug. 18 ("Diane")	B	(2)(3)	Passed just south of Long Island and about over Nantucket. Brought record rainfall to many areas of Conn.; heavy flood damages in river valleys; no important tidal-flood damage along coast.

Notes

(1) The following assigned categories pertain to the effect of a hurricane on the coast of Connecticut.

A: Caused severe tidal flooding.
B: Caused damage from wind and rainfall. (usually accompanied by high seas and moderate tidal flooding).
C: Threatened the area.

Notes (cont.)

(2) "Hurricanes - Their Nature and History" by I.R. Tannehill (1956).

(3) Local newspaper accounts, histories, etc.

(4) Material furnished by U.S. Weather Bureau.

(5) Information furnished at public hearing at Pawcatuck, Conn.

TABLE A-2

SUMMARY OF OTHER NOTABLE STORMS THAT CAUSED HIGH TIDES ALONG THE CONNECTICUT COAST

Date of Storm	Remarks
1639, March 16	"There was so violent a wind at south-southeast and south as the like was not since we came into this land. It began in the evening, and increased till midnight. It overturned some new strong houses; . . . It tare down fences - people ran out of the houses in the night, . . . There came such a rain withal, as raised the waters at Connecticut 20 feet above their meadows, etc. (Winthrop's Journal "History of New England, 1630-1649".)
1767, Jan. 12	"A great variety of articles have been found on the north side of Long Island supposed to have drifted from this colony (New London), in the late great freshet, among which are boats, timber, parts of houses, stacks of hay, etc." (The Massachusetts Gazette and Boston Weekly News-Letter.)
1767, Dec. 14	"From the southward we hear, that the gales . . . did considerable damage to the wharves and shipping at Newport, Stonington, New London, etc. The tides rose higher than had been known for many years in those places . . . Eleven sail bound up the Sound were drove ashore at Stonington . . . It is said the wind, which was at west-southwest was the most violent ever known along that coast." (The Massachusetts Gazette and Boston Weekly News-Letter, No. 3351).
1771, Feb. 9	"Last Saturday morning came on a storm of snow and hail, which soon changed to rain, and the wind varying to the south-east brought into the harbor (New Haven) the fullest tide ever known, which ebbed and flowed two or three feet in a few minutes; and at the time it was

TABLE A-2 (continued)

SUMMARY OF OTHER NOTABLE STORMS THAT CAUSED HIGH TIDES ALONG THE CONNECTICUT COAST

Date of Storm	Remarks
1771, Feb. 9 (cont.)	expected to be low water, the tide was above high water mark. Great quantities of lumber were floated from the wharves, and a great deal of sugar, salt, etc. destroyed. A Brig and two sloops were drove ashore in the harbor". (The Massachusetts Gazette and Boston Weekly-News Letter, No. 3513.)
1869, Oct. 3	"A fearful gale prevailed all yesterday along the Atlantic border and even carried its disasterous effects far into the interior. The rain fell in torrents, and great damages by floods are reported from every quarter." (Norwich Morning Bulletin.)
1895, Feb. 7	"During the gale and high tide here (Stonington) Friday . . . the water flooded the engine room of the Atwood Machine Company. This is something that was never known to happen before. The damage at Eastern Point is more extensive than was first thought. People at the Point say they never before experienced such gales and such tremendous seas. The wharves will all have to be repaired. Some of the dwelling houses too present a very bedrabbled appearance." (The Day, New London, Conn.)
1896, Feb. 9-10	"The worst northeast storm of the season . . . has raged here (New London) all day. The surf is higher than it has been since the spring storms . . . The rainfall from its commencement Thursday up to 3:00 today (Friday) amounted to 5.16 inches and at that time was falling at the

TABLE A-2 (continued)

SUMMARY OF OTHER NOTABLE STORMS THAT CAUSED HIGH TIDES ALONG THE CONNECTICUT COAST

Date of Storm	Remarks
1896, Feb. 9-10 (cont'd)	rate of three fourths of an inch an hour. . . The usual channels towards the river in all parts of the city have been overtaxed causing the water to set back and overflow the roads, meadows, yards, etc. and converting many of the cellars into lakes. From Bloomingdale back for a long distance the country is flooded and the roads covered with water to a depth of a foot in many places." (The Day, New London, Connecticut)
1950, Nov. 25	Tide rose to 7.2 feet above mean sea level at Pawcatuck, Conn.
1951, Nov. 3	Tide rose to 6.0 feet above mean sea level at Pawcatuck, Conn.
1953, March 16	Tide rose to 7.1 feet above mean sea level at Pawcatuck, Conn.
1955, Oct. 17	Tide rose to 6.5 feet above mean sea level at Pawcatuck, Conn.

A-3. DESCRIPTIONS

Brief descriptions of type "A" and "B" hurricanes experienced along the Connecticut coast, as reported in newspaper accounts, or obtained from other records, are given below. Also included are descriptions of six hurricanes (Category "A") that are reported to have struck Rhode Island and Massachusetts and which are believed to have affected Connecticut but for which no records have been found regarding their effect on the Connecticut coast.

a. 15 August 1635. From: "Of Plymouth Plantation, 1620-1647," by William Bradford.

> "This year the 14 or 15 of August (being Saturday) was such a mighty storm of wind and rain, as none living in these parts either English or Indian, ever saw, being like (for the time it continued) to those Hauricanes and Tuffons that writers make mention of in the Indies. It began in the morning, a little before day, and grew not by degrees, but came with violence in the beginning to the great amazement of many. It blew down sundry 211 houses, and uncovered others; divers vessels were lost at sea, and more in danger. It caused the sea to swell (to southward of this place) about 20 feet, right up and down, and made many of the Indians to climb into trees for their safety; it took off the board roof of a house which belonged to this plantation at Manamet, and floated it to another place, the posts still standing in the ground; and if it had continued long without the shifting of the wind, it is like it would have drowned some part of the country. It blew down many many hundred thousands trees turning up the stronger by the roots, and breaking the higher pine trees off in the middle, and the tall young oaks and walnut trees of good bigness were wound like a withe, very strange and fearful to behold. It began in the southeast and parted toward the south and east, and veered sundry ways; but the greatest force of it here was from the former quarters. It continued not (in the extreme) above 5 or 6 hours, but the violence began to abate. The signs and marks of it will remain this 100 years in these parts where it was sorest. The moon suffered a great eclipse in the second night after it."

From: "The History of New England from 1630 to 1649," by John Winthrop.

> "...This tempest was not so far as Cape Sable, but to the south more violent, and made a double tide all that coast...

"The tide rose at Narragansett fourteen feet higher than ordinary and drowned 8 Indians flying from their wigwams."

b. 3 August 1638. From: "The History of New England from 1630 to 1649", by John Winthrop.

"In the night was a very great tempest or hiracano at Southwest which drave a ship on ground at Charlestown, and brake down the windmill there, and did much other damage. It flowed twice in 6 hours, and about Narragansett it raised the tide 14 to 15 feet above the ordinary spring tides, upright."

c. 12 November 1641. From: "The History of New England 1630 to 1649", by John Winthrop.

"A great tempest of wind and rain from the southeast all the night, as fierce as an hurricane. It continued very violent at Northwest all the day after. Divers boats and one bark were cast away in the harbor, but (which was a wonder to all) no dwelling house blown down, nor any person killed; and the day after it came to southeast again, and continued all the night with much wind and rain; and thereupon (it being about the new moon) followed the highest tide which we had seen since our arrival here."

d. 30 October 1723. From: "The Boston News-Letter, No. 1033. Thursday, November 27 to Thursday, November 14, 1723."

"Rhode Island, November 1 ....

"....On Wednesday last we had here a very great Southeast storm of wind and rain, and a very high tide, a foot higher than ever was known before, which has broken and carried away several of our wharves, and drove some vessels ashore from their anchors, and has done considerable damage in warehouses and cellars, to dry goods and other merchandise; the loss is computed to some thousand pounds."

e. 24 October 1761. From: "The Boston News-Letter No. 2991. Thursday, October 29, 1761."

"There was a hard gale of wind which brought the highest tide into the harbor of Providence in Rhode Island that hath been known in the memory of man, and

carried away the great or Weybosset Bridge. Five or six vessels were drove ashore and greatly damaged, and it being high water there, it got into the stores and cellars and damaged sugars, etc. to the amount of 12 or 15000 pounds their currency. On both roads East and West, so far as we have heard, the roofs of houses, tops of barns and fences, have been blown down, and it is said thousands of trees have been torn up by the roots by the violence of the above storm, and we fear we shall hear melancholy accounts of damage done at sea."

From: "Memoirs of Rhode Island 1636-1783", by Henry Bull.

"From the Newport Mercury of October 27, 1761 -On Friday last came on a terrible storm from the Northeast, which continued increasing with a very heavy rain, and did not abate till after 2 in the morning. The violence of the wind broke off part of the steeple of the Trinity Church. Several persons sustained considerable loss in their sugar, salt, etc. by the prodigious rise of tide, which flowed into their stores and cellars. Many of the ships in the harbor were driven ashore from the wharves and their moorings, but without any considerable damage except to two ships. Sad havoc has been made with the lumber and wood on the wharves, great quantities of fence blown down and numbers of trees torn up by the roots. People hardly thought themselves safe in their own houses, for a more violent storm has scarce ever been known here."

f. 19-20 October 1770. (Type "A") "History of the State of Rhode Island", by Samuel Greene Arnold.

"A violent storm again blew down a part of the spire of Trinity Church at Newport and caused an immense loss of life and property along the coast. Newport suffered very severely in this gale."

From: "The Connecticut Journal", November 21, 1770.

"New London, Oct. 26.

"On Friday Night and part of the next day we had a very severe Storm of Wind and Rain from the N.E. by which two Vessels were drove ashore in this Harbor but received little or no damage."

g. 19 September 1787. (Type "B"). From the diary of William Wheeler in "Black Rock, Seaport of Old Fairfield, Connecticut, 1699-1870."

> "Line storm. A mill at Stamford carried off whole and Norwalk bridge floted."

h. 19 August 1788. (Type "B"). From the diary of William Wheeler in "Black Rock, Seaport of Old Fairfield, Connecticut, 1699-1870."

> "The hardest gale that has been for many years -- at 1 o'clock a Sloop and Schooner went on shore---. The gale reached 100 miles up country, in some places shifting from SE to NW & twisting of trees 9 inches in diameter--it moved Carson's house about 6 feet."

From: "The New Haven Gazette and the Connecticut Magazine," Thursday, August 21, 1788.

> "New Haven.
>
> "Last Tuesday morning came on a violent gale of wind from the South, which at about one o'clock, P.M. veered to S.S.W. and blew a perfect hurricane.
>
> "Several vessels were driven ashore and very material damage is done to the long Wharf--We expect to hear of much damage done at sea and in the harbours on our coast..."

From: "The Connecticut Courant and Weekly Intelligence," Monday, August 25, 1788.

> "New Haven, Aug. 20.
>
> "Yesterday we had a violent gale of wind, the height of which was from the S.E. about one o'clock. Though the tide was not full as has been frequent in easterly storms, considerable damage was done to the Long-Wharf by the violence of the waves and several vessels parted their masts, but the shipping received no material damage. The Indian corn is much injured and the trees stripped of their fruit and some apple trees blown down."

i. 9-10 October 1804. (Type "B"). From: "The Connecticut Courant," (October 17).

> "The partial and summary accounts which have been

received from the neighboring towns, though they afford no particulars of the effects of the late gale, sufficiently evince the widespread destruction which has been experienced by it. In all most every direction the fruit and other trees have been generally blown down, the fences destroyed and much damage done by the heavy rain, which fell during the storm."

j. 22-23 September 1815. (Type "A"). From: "Connecticut Herald," (New Haven) September 26.

"The storm,--- On Friday night and Saturday morning last a severe storm of wind and rain was experienced in this vicinity...The most material injury sustained here was to Long Wharf, which was entirely inundated by the highest tide known for a great number of years. Everything movable on the wharf was swept away. The water in some of the stores was nearly two feet deep, but no great loss of property took place except in a quantity of rum which was swept from the wharf, several hogshead of which have not yet been recovered..."

From: "The Connecticut Courant," October 2.

"Bridgeport, Sept. 27.

"The late Storm which commenced on Thursday last continued with increasing violence until 11 o'clock on Saturday morning. The wind during the whole time blew a severe gale accompanied with rain from the N.E. and had so much increased the waters in the Sound that the tide, which in ordinary weather would have been full at 2 o'clock and 44 minutes, attained its greatest height at 12 o'clock 30 minutes, and was then near six feet above common flood tides; and had it not fortunately happened that the wind some hours before the tide was at full veered round to the N.W. it must have risen to an alarming height. The oldest inhabitants do not remember so high a tide by nearly one foot. The water through the whole length of Water Street was of sufficient depth for the largest long boat to pass loaded with passengers. Considerable damage has been sustained in the stores along the shore by the destruction of salt, grain and other bulky articles that could not speedily be removed.

From: "Norwich Courier", September 27, 1815.

"Norwich.

". . . .

"The damage done in this town and neighborhood by the violence of the wind and the extraordinary rise of the tide, is great beyond precedent. Scarcely a store on the wharves has escaped injury - some of them have been entirely swept away - and goods to a considerable amount damaged or destroyed. The water on the wharves and the Lower Street was 4 feet higher than can be remembered on any former occasion..... The water beat over the wharf bridge with incredible force. Its depth there was at least 6 feet; and such was the fury from the action of the wind, that the market and a store adjoining were carried away. Immense numbers of trees, of every description, were levelled to the earth - As also fences in all direction.

"New London.

"The effects of the gale within New London we understand were very much more severe than at this place. The wharves were ruined, and the shipping has suffered dreadfully. Many of the buildings on Beach Street are swept away - others unroofed - and fences and trees blown down in every direction."

"Stonington.

"The tempest rages with extreme violence. A number of vessels bound to the eastward had put in here for a harbor, every one of which was driven on shore."

k. 2-3 September 1821. (Type "A") From: "Connecticut Herald," (New Haven), Tuesday, September 11.

"We were visited in the evening of the 3d inst. by a toronado almost unexampled in this latitude. The gale commenced at S.E. about 6 o'clock but was most violent from 8-10, the wind then varying from S.S.E. to S.W.--nearly all the vessels in the harbor were driven by the force of the storm, and are more or less damaged.. Fortunately at the height of the gale, it was time of low water; otherwise, damage

to shipping, wharves, stores &c, must have been incalculable...The rafters and gable end of a brock store on the wharf...were blown down...part of the roof of Mr. Thomas Hunt's dwelling in Water St. was torn off...scarcely a street was exempted from fallen chimnies and fences. Several trees were upturned by the roots...the leaves of most of which remain are changed to a singular dark brown hue.

"Part of the first bridge on the pier was carried away by the driving of a sloop, who struck upon her stem.

"At Bridgeport, several buildings were blown down or unroofed..Almost all the vessels in port were driven ashore, but without much injury.

* * *

"New London, September 5.

"Severe Gale. --On Monday night last we experienced a severe gale from the South-East. It commenced about 7 in the evening and lasted until midnight. The tide rose several feet above its ordinary level and some damage was done to our wharves and boats..."

From: "Black Rock, Seaport of Old Fairfield, Connecticut, 1699-1870."

"A tremendous gale of wind E & SE from 6 to 11 in the evening passed over this place--torn down many...trees...every vessel went ashore in this harbor-- a sloop dismasted in the sound and the lighthouse laid flat. The hardest gale ever remembered.

"The leaves of the trees as in 1788 are turned brown..small limbs of trees blew thirty rods--- there was a continual roaring like thunder..."

1. 4 October 1841. (Type "B"). From: "Hartford Daily Courant," Tuesday, October 5.

"Severe Storm--We have been visited by a most remarkable storm--the like of which, so early in the season, on account of its severity and comtinuance, is not remembered by our oldest inhabitants. On

Saturday night it commenced raining, the wind from the northeast, and continued without intermission, intermingled a part of the time with snow and accompanied by wind until sometime yesterday afternoon. During a part of Sunday night, the wind blew a perfect hurricane, and the rain came down in torrents.. Many valuable fruit and ornamental trees have been prostrated or stripped of their limbs... as the storm undoubtedly extended along the coast, we may expect to hear of damage from that quarter."

m. 29-30 October 1866. (Type "B"). From: "Hartford Daily Courant," October 31.

"One of the hardest storms of the season prevailed on Monday and continued through yesterday. It was a regular southeaster--one of those violent storms that often haunt us at this season of the year--The wind prostrated the lines between New Haven and New York and at other places east and south. The steamer Granite State left New York at the usual hour on Monday and met with rough weather on the Sound..."

n. 8 September 1869. (Type "A"). From: "Norwich Morning Bulletin," September 12, 1869.

"Storm (at Mystic, Conn.) worst since 1815. Came at low water and the tide, though rising higher than it has for 2 or 3 years, did less damage than it otherwise would have done. Had it occurred at highwater, the bridge and a large part of Mystic would have been submerged. The tide rose at the rate of an inch a minute, walling up a foot high where it struck the spiles at the bridge."

o. 23 October 1878. (Type "A"). From: "The Daily Standard", Bridgeport, October 23, 1878.

"A section of the fence...opposite the depot blew down this morning.

"A portion of the bulletin board corner High and Main Streets blew down this morning. Limbs were broken off the trees in all sections of the city.

"The storm last night and this morning drove a number of small boats ashore below the Naugatuck dock and their owners turned out and dragged them beyond reach of the waves...

"The sea held high carnival at Sea Side Park this morning, and a wilderness of rolling white caps and tempest of dashing spray bore witness to the disturbed mood of the waters, angered by the howling winds..."

From: "Greenwich Observer," October 24, 1878.

"....The storm yesterday was very severe and the shipping in our harbor was roughly tossed. The tide rose to a remarkable degree..."

From: "The Daily Standard," Bridgeport, October 24, 1878.

"New Haven, Oct. 23d, --The steamer John Bramhall, Captain Pollard, from this city, ashore on Little Cull Island, has gone to pieces in the gale."

p. 18 August 1879. (Type "B"). From: "Stamford Herald," (Weekly) August 20.

"---From a test made at Waterside the rainfall during the late storm was found to be 8 inches. On Monday from 7 a.m. to 7 p.m. a little over 4½ inches fell.

"A more soaking continuous and persistent rainstorm we have seldom experienced in August...corn has suffered under the infliction of so much rain and wind..."

q. 10 September 1889. (Type "A"). From: "The Greenwich News." Friday, September 13.

"The furious northeaster which has been raging along the Atlantic Coast for the past few days is one of the severest storms known in this vicinity for years, and one of the most destructive to property. Ever since Tuesday when the storm reached here from the Atlantic, it has blown a gale, mostly from the northeast, accompanied nearly all of the time by rain.

"The greatest force of the storm has been felt along the coastline...small craft along the shore have suffered severely...

"Greenwich has suffered comparatively little from the storm. A few trees have been blown down and the roads have been damaged more or less, but beyond this there was scarcely any damage done. On Tuesday there was a very high tide in the harbor and at one time part of the steamboat dock was under water...the only loss reported along the shore are one or two row boats."

* * *

"The schooner Annie Jacobs from New Haven... was beached on Mansuring Island during the storm Tuesday night."

From: "The Westerly Narragansett Weekly", September 19.

"The high surf last week drew crowds of sight-seers to Watch Hill from Westerly, Stonington and Mystic. It was a grand sight to see the big waves come rolling in, until apparently they were about to swamp the land. Not much damage was done except the destruction of the Peninsula House. . . ."

r. 23-24 August 1893. (Type "A") From: "Stamford Advocate," August 24.

"One of the most severe storms of wind and rain ever experienced in this locality started last night and continued increasing in force until this forenoon. The evidence of its severity were to be seen on every hand . . streets washed out and flooded, buildings damaged...

" . . . Every boat in the harbor was adrift . . . The tide rose higher than has ever been known for some time. All the streets in the vicinity of Waterside were impassable, the water coming up over the meadows to the foot of Atlantic Street . . .

"The scene in the lower harbor at high tide this morning was a wild one . . . On the whole the craft in the lower harbor escaped well, much better probably than they would have done had a gale of equal force come in from the southwest."

s. 29 August 1893. (Type "A") From: "The Columbian Weekly Register," (New Haven), Thursday, August 31.

"Early this morning the wind blew 50 miles an hour, breaking all previous records . . . Late last night the barometer recorded 29.98, but it was only 29.38 early this morning. . .

"The waves swept in with terrible fury all along Savin Rock shore. They had full play at the docks made of logs and boards and stone. When the tide was high, about 8 o'clock, the water came up over Beach Street and threatened to enter the handsome shore cottages that front the harbor from Skeele's pavilion to O'Connell's hotel on the Rock . . . mud from the street was picked up by spray and spattered on the windows . .

"The waves leaped into the air 20 or 30 feet at a time . . .

"The waves were . . . tumbling upon the street in front of the Surf House and were making their way into the ground floor of the hotel. The tide was at its height and soon after began to recede; with the falling of the tide the danger that threatened the house in being overflowed with a part of Long Island Sound subsided . . . The dock or wharf front of logs and boards was partially demolished. Mr. Cox's damage will be at least $500.00 ...

"But the storm's destructive power was felt in dead earnest at Stewart's pavilion and thereabouts in front of Sea View hotel. The Sound took one bite out of the solid earth in front of Stewart's that was 75 feet long and 10 and 20 feet wide in some places...

"The wind was tearing over Savin Rock at a 60-mile gait."

From: "The Westerly Narragansett Weekly," August 31.

"Mystic.

"The storm did considerable damage. The schooner ... broke loose from her bow fastening, drifted out lengthwise of the river, making a blockade. Telephone and telegraph lines are down. Numerous washouts occurred on railroad lines (in the area around Mystic)."

t. 9-10 September 1896. (Type "B") From: "Greenwich Graphic," September 25.

"Between five and six o'clock on Saturday night it rained and blew in a way that caused many people to be frightened. It was the most severe storm we have had this summer...From William St. to Putnam Ave. it was impassable after the storm.

The wind twisted the great trees and broke them as though they were pipe stems...The rain came down almost in torrents and on Greenwich Avenue the water flowed in the gutters like the stream from a large brook."

From: "The Day", Thursday, September 10.

"Groton.

"There is no doubt but what the wind could have blown harder than it did Wednesday night, but there is no one hereabouts but what is satisfied it blowed hard enough. The twigs and branches of the trees that strew the streets this morning was evidence of its destructive power. No greater damage outside of the breaking of trees was reported."

u. 16 September 1903. (Type "A") From: "The Bridgeport Daily Standard," September 17.

"Very strong winds and rain unroofed houses, felled or uprooted trees.

"...a casual survey of the damage along the waterfront shows that it will run into the thousands...

"At the Bridgeport Yacht Club in the Black Rock harbor there was damage galore, and but for the active work of the yachtsmen there would have been several fine yachts totally wrecked.

"Although the waves were very high the water did comparatively little damage...no water ever reached the roadway although everybody was completely drenched with the spray which rose in a long continuous, heavy white cloud the whole length of the sea wall."

From: "The Westerly Daily Sun", September 17.

"New Haven.

"Southwest Connecticut came within the radius of the storm which swept up the Atlantic coast and the fury of the elements did greater damage than any disturbance of a like character in the month of September for a great many years. Trees were ripped up, telephone and telegraph wires were torn down...At many

places small craft were dashed to pieces on the shore. Crop damage was severe."

From: "The Daily Advocate," Stamford, September 16.

"The storm which is raging all over this section struck Stamford with a vengeance at noon today and inside of an hour it had shaped itself into what old-timers say, is the swiftest easterly storm experienced for twenty years or more...

"On the east shore of Shippan, the storm was felt with great severity, and the same is true of Sound Beach where there are a number of summer cottages near the shore.

"The wind blew great guns...rain fell in veritable sheets. On exposed corners this was particularly noticeable, the pavements being under a constant wash of water...The wind came from the east and blew at from 75 to 80 miles an hour."

v. 15 September 1904. (Type "B"). From: "New Haven Evening Register," September 12.

"At one time early this morning, shortly after midnight the wind being then at the southwest, blew at the rate of 40 miles an hour....During the entire progress of the storm in New Haven 3.96 inches of rain fell... At Casey Beach, during the early part of the storm, the shore was heavily lashed by angry waves and for a time it seemed as though some of the lighter of the houses would be thrown from their foundations. Then the wind shifted and blew offshore and the water smoothened.... Trees were uprooted and oyster beds damaged by the winds..."

w. 9-14 November 1904. (Type "B") From: "New Haven Evening Register," November 14.

"Here in New Haven the wind in yesterday's gale blew as high as 50 miles an hour. Many telephone and telegram wires were prostrated and there was some light wreckage about the harbor..."

x. 1 October 1920. (Type "A"). From: "The Daily Advocate," Stamford, October 1.

"The wind attained a velocity of 60 miles an hour, and it roared along the shorefront in an alarming manner, but did no great actual damage there. It veered from south by east, late in the afternoon to a more southerly

direction as the night wore on. Its greatest velocity was attained about midnight. That was sufficient to rock some houses on their foundations.

"Boats were torn from their moorings and trees were blown down."

* * * * *

"Norwalk, Oct. 1. --Last night's storm here was the worst in years, doing damage along the Sound shore. The tide reached a record height at 1 a.m., the water covering the roads and wrecking a number of cottages at Belle Island... 12 small boats were carried ashore and wrecked...and much damage done by the wind."

"New Haven, Oct. 1. Thousands of dollars of damage was done along the Sound shore last night by one of the worst storms in several years. Driven by a gale which exceeded 40 miles from the southeast and accompanied by a high tide. The waves rolled mountain high against the beach during the night, the tide reaching a record height about midnight. Many boats were washed ashore, cottages, piers and breakwaters being partially wrecked.

"At the Weather Bureau this morning it was stated that the wind reached a velocity of 42 miles at the height of the storm. A total rainfall yesterday and last night of 2.51 inches was recorded."

From: "The Day," October 1.

"New London

"The gale which swept the east last night and early this morning did a large amount of damage in Connecticut, principally to telephone, telegraph and trolley systems, caused the wrecking of 3 barges near this city and brought loss to rural districts through the destruction of late crops and fruit.

". . . . . .

"New London was visited by an unusually severe wind and rain storm Thursday. The storm which began early in the day developed into a gale Thursday night, the wind blowing with a velocity of about 80 miles an hour when it reached its height about midnight. The damage was considerable but not serious.

Telephone and electric wires were blown down, limbs were ripped off trees and in one or two instances trees were uprooted. Shipping on the Sound was delayed."

y. 26 August 1924. (Type "B"). From: "Stamford Sentinel", August 27.

"Nothing like the devastation of felled wires, cables and poles in the eastern part of the state ever has been experienced by the telephone people..."

* * *

"New Haven, Conn. Aug. 27. ---With approximately 6,000 telephones out of commission in the territory east of Saybrook, a section of the state severely hit by a juvenile tornado late yesterday afternoon, the Southern New England Telephone Company suffered more damage than ... in a great many years..."

z. 3 October 1929. (Type "A") From: "New Haven Journal-Courier," October 3.

"Damage which will probably total thousands of dollars was done yesterday along west shore in Milford by the lashing northeaster which swept northward from the Caribbean..its ferocity had been largely spent by the time it had reached the shores of Long Island Sound...

"The largest damage reported from along the shore yesterday came from Silver Beach in Milford where the strong northeasterly and easterly gale created waves at the high tide hour this morning which tossed one cottage off its foundations...

"The water overflowed the trolley tracks and in some places covered the Milford shore road to a depth of two feet...the storm concentrated its fury on the Milford shore...

"High tides came near flooding street car tracks where they pass close to the water's edge on the shore runs, it was said, but no delays were brought about by this cause.

"Official figures...for total rainfall...of 2.03 inches between 8 p.m. and 8 a.m. yesterday and precipitation for the 12 hours after 8 a.m. yesterday being 1.30 inch.

"The wind velocity at both 8 a.m. and 8 p.m. was 12 miles per hour atop the post office building, but reports had velocities of 25 miles an hour at Milford."

aa. 17-26 August 1933. (Type "A"). From: "Daily News-Graphic," (Greenwich) August 24.

".....HURRICANE'S EDGE WHIPS ACROSS TOWN.

".....the gale swept the madly rolling Sound. A total rainfall for the week of 3.71 inches was reported by the Water Company here, enough to flood a less undulating country."

From: "Bridgeport Post," August 24.

"GALE TEARS DOWN TREES...AS WAVES POUND SHORE:
DAMAGE ALONG COAST SET AT MILLIONS

"....the storm accompanied by a driving rain, whipped the Sound into a fury, halted shipping and threatened many shore cottages as it gathered velocity with the rising tide early this morning...

"....little damage was reported...on Long Island Sound side of town although exceptionally high tides and turbulent seas were reported."

From: "The Sun", Westerly, R.I. August 24.

"Raging seas which for several days have threatened life and property at Watch Hill (Rhode Island) and other neighboring shore resorts reached their height last night, shortly before midnight and appeared to be on the wane.

"Made turbulent by a 60 mph gale which swept along the entire Washington County sea coast, giant combers crashed high against bulwarks and homes, seemingly centering their attack along Napatree Point, Watch Hill, where the only severe damage was reported.

"The waters swept high over the dunes at Napatree Point carrying thousands of tons of sand which were deposited along the Fort Road. . . . The storm subsided suddenly as the tide started outward."

"Stonington.

"The storm at Stonington has been severe the past few days and last night the high northeast wind changed to the southwest, bringing a hard rain, driven by the high wind . . . .All night long the waves lashed about the point and the sea combed all of the Stonington breakwaters . . . . The old dolphin has entirely disappeared and left a pile of rocks as a further menace to navigation."

bb. 9 September 1934. (Type "B") From: "Stamford Advocate," September 10.

".....Saturday night's furious storm did thousands of dollars' damages.

"The storm lashed at the New England coast, battering the Connecticut area with such fury that it left a trail of havoc, especially in Stamford and the surrounding towns... Trees were uprooted...cellars and streets flooded..."

From: "Daily News-Graphic," (Greenwich) September 10.

"HIGHWAYS WASHED OUT BY HEAVY RAINFALL.

"...an 85-mile-an-hour gale and nearly three inches of rain...Saturday night...felled trees and flooded cellars in all parts of town."

cc. 19 September 1936. (Type "B"). From: "Daily News-Graphic" (Greenwich), September 19.

"HURRICANE DRIVEN GALES STREW GREENWICH WITH DEBRIS

"...trees uprooted...boats torn from their moorings in Greenwich Harbor, but scattered damage was not of record proportions...

"The gales, driving toward the Sound, came in the backlash of the southern hurricane that roared up the Atlantic coast...

"Rainfall varied from two inches in the vicinity of Greenwich Water Company's Putnam lake filter plant to 2.76 in central Greenwich nearer Long Island Sound...

"Stamford police reported that Stamford was 'very lucky', no serious damage. Wires and branches were reported down in several places."

From: "Bridgeport Post," September 19.

"A tree-toppling gale...swept through Fairfield County last night and early today at a velocity of 45 miles an hour...wrecking damage of thousands of dollars. It was accompanied by torrential sheets of rain."

From: "Stamford Advocate," September 19.

"A howling wind, which drove before it a heavy rain, swept over Stamford last night and early today, disrupting telephone and electrical service in the town and city...

"...the rainfall, recorded at two inches, continued at intervals...

"...no damage to shipping...Several boats dragged from their moorings."

dd. 21 September 1938. (Type "A") From: "The Day", New London, September 22.

"The gale striking the city about 3:00 p.m. yesterday, jolted the city into a twisted mass of wreck and ruin, tearing roofs off buildings, uprooting trees, caving in brick walls and blowing out windows. There are 4 known dead, 5 missing and at least 75 injured.

"Never before has New London seen such a terrific catastrophe. Streets piled with debris, fires raging in a gale estimated at 90 miles an hour...

"Meanwhile, an unprecedented tide accompanying the hurricane drove the Thames River over its banks. The raging waters climbed 4 to 6 feet above the roadbed of the New York, New Haven and Hartford railroad tracks, flooding the Union Station...

"The howling wind was estimated to have velocity as high as 120 miles an hour at Fishers Island.

"The pounding wind and tide made a shambles of the Ocean Beach section. The boardwalk and 50 or more summer cottages bordering it, together with cottages in the Neptune Park section were demolished.

"At least one death and an unestimated number of injuries were revealed in Groton Borough this morning, along with property damage that runs into thousands and thousands of dollars...

"Shennecossett beach buildings were picked up and flung back onto Beach Pond road. The beach club site is marked by a few piles.

"Bluff Point and Jupiter Point were described today as barren promontories, with practically all cottages there washed into the Poquonoc River and Bakers Cove. Groton Long Point and all other places along the waterfront suffered similar disasters. Property damage in the wealthy Eastern Point section was enormous.

"The rain was driven by a southeast wind... Rainfall of 4.08 inches was recorded from 4:30 o'clock yesterday afternoon to 7:30 o'clock this morning, and it was this tremendous volume of water that gave the final 'kick' to streams which already had mounted high.

"This rainfall reading was made at Lake Konomoc, the city's main reservoir at Waterford, which raced upward eight and one-quarter ($8\frac{1}{4}$) inches during yesterday to go 12 inches above spillway level. The water was rushing in a sweeping fall 6 inches above emergency flash-boards. The City Engineer reported that the rainfall at the Reservoir since Saturday was 10.01 inches.

"Damages due to the hurricane and the fire which started during the hurricane were estimated at $4,000,000.

"NORWICH

"Norwich where the Thames River starts, is on tidewater. The Yantic and Shetucket Rivers meet to form the Thames. All Rivers were up to their banks when the hurricane hit. Three hours later the tide backed the water up 11 feet in one hour. Most river towns know when their water is rising 6 inches to the hour and the people can do something about belongings. When water rises 11 feet in one hour as in Norwich everyone just runs for high ground.

ee. 14 September 1944. (Type "A"). From: "The Day", New London, September 15, 1944.

"The tropical hurricane, which had been sweeping up the Atlantic from the Bahamas, struck this section last night to exact a toll of 2 dead and 2 injured and property damage as yet unknown but estimated to be very heavy. It halted rail, bus and automobile traffic, uprooted trees and poles, leveled beach pavilions, wrought great loss at shore resorts, left practically the entire city without light or power, sank many boats and tossed others up onto the shore in this city and at Niantic, principally washed out railroad tracks, greatly interrupted telephone and wire service.

"Not nearly as violent or as far reaching in its effects as the great hurricane of September 21, 1938, the storm made up of a wind that attained an official velocity of 95 miles an hour, a torrential rain and high seas that assumed in some areas, the aspects of a tidal wave. . . . . .

"The local hurricane damage was particularly severe along the lower water front and Osprey, Guthrie, Pequot Point, and Rogers beaches were completely destroyed and the entire south section of the concrete walk at Neptune Park was carried away and at least 4 of the cottages on the walk were undermined.

"The tremendous tide and angry surf completely leveled the bathing pavilions at Osprey and Pequot Point beaches, all the cabanas and lockers at Guthrie beach were carried away, and at Rogers beach the bathhouses were damaged beyond repair, and the raft was dragged from its anchorage and hurled bottom-side up onto the beach.

"When the tide was at its height and the storm at its peak the sea surged completely over the tops of the pavilions at Osprey and Pequot Point beaches and over the wall into Pequot Avenue. At Neptune Park the waves started battering the boardwalk or sea wall early in the evening and eventually cascaded over it to pound at the houses bordering it.

"The Braunstein-Freres plant which was partially demolished in the hurricane of 1938, took another beating last night and the damage will run into thousands of dollars, according to the Manager. The tidal waters and rain poured into this building to flood it to a depth of about 9 inches. In the front or main building there was 4 inches of water....

"The storm caused little damage above the Thames River Highway bridge . . . .

"The tide swept up over the walls at the ship yard and flooded the yard and several buildings . . . .

"The old road to Norwich - Williams Street extension through Quaker Hill - was blocked late in the evening when the water of Smith Cove backed up over the road. It was 2½ to 3 feet deep where Hunt's Brook enters the Cove, and impassable. At the bend of the road, near the Quaker Hill firehouse, the waters of the cove also backed up, partly flooding the lower floor of the store and Quaker Hill Post Office, . . . but in the basement the water was over the top of the furnace, water pump, etc.

"In most of the cases of flooding of roads along various coves of the Thames River, the high water came well after the time of high tide, in the evening. The water backed up the most, it appeared, about 11:00 o'clock while high tide in New London was supposed to be at 8:27 p.m., war time, last night.

"Niantic's shoreline again received the full blast of last night's hurricane but the damage was not as severe as in 1938. Niantic beach suffered damage estimated at between $4,000 and $6,000 during the hurricane, according to an estimate of its owner.

"At Crescent beach the tide came over the beach onto the road by the Elms Hotel and the cottages on White beach in front of the fresh water pond were surrounded by water, but little damage was done.

"A total of 4.02 inches of rain - more than half an inch an hour - fell in New Haven from 6:00 p.m. yesterday until the hurricane abated early today, and the figure for Hartford was 4.05 inches.

"One fact which perhaps prevented greater damage was that the wind blew against the tide which was high at the height of the storm, holding back the surging water of Long Island Sound to a great extent."

ff. 31 August 1954. (Type "A") From: "The Day", New London, August 31, 1954.

"A multi-million dollar devastation along the southeastern Connecticut shore line. The wind damage was nowhere near as great as in the 1938 hurricane. Sea water rose higher, at least at several points in this harbor where buildings showed comparable tide marks.

"The fury of the storm struck at about 10:00 a.m., almost 2 hours before full high tide. High tide was at 11:55 a.m. Had the heart of the storm struck then, damage undoubtedly would have been worse. As it was the water rose an estimated 6 feet above the normal high water mark, flooding shore areas.

"Damages may run to $5,000,000 between the Connecticut and Pawcatuck rivers and up the Thames to Norwich. Twenty to 25 cottages were wrecked at Point O'Woods, the most concentrated disaster, closely followed by the Stonington, Lord's Point, and Jupiter Point home and cottage losses.

"A survey indicates that 2,488 cottages on the shoreline between East Haven and the Rhode Island line were either destroyed or damaged. The survey also indicated that 1,889 boats of all kinds and 129 automobiles were either ruined or damaged. Approximately 75,000 bushels of apples are on the ground, representing a loss of about $150,000. The County Agent said damage to apple and peach trees themselves, many of which were blown down, may hit $25,000.

"NOANK.

"The high tide, coming about an hour after the climax of the gale, pushed water about 7 feet above normal and flooded homes and wells in low-lying sections of town. Automobiles left near the shore were under water for hours.

"OCEAN BEACH

"Damage estimated at $36,000 to concessionaires amusements. At the height of the storm there was about 3 feet of water in the inclosure. Most of the damage was from water but there was some wind damage.

"MYSTIC.

"The main streets of Mystic were under 4 feet of water during the storm.

From: "The Sun", Westerly, Rhode Island, August 31, 1954.

"Practically every ground floor store and shop in the Pawcatuck business district was ravaged by high water at noon. Loss estimated at $100,000.

"In many of the West Broad Street business places, including Shea's news stand and the modern Grill Restaurant, the water reached 2 feet above floor level. . . . the water was about 1 foot higher during the hurricane of 1938."

gg. 11 September 1954. (Type "B") From: "The Day", New London, September 13.

"She (hurricane) stabbed the area for 8 hours Saturday ...

"She deposited more than 6 inches of rain - a record - and caused floods in areas where brooks overflowed or the catch basins couldn't contain the water.

"She might have done more damage, but she spent most of her fury in this area at a time when the tide was at low ebb.

"The Groton filtration plant at Poquonoc Bridge reported a fall of 6.15 inches from midnight Friday to 3:00 p.m. Saturday, a record for a 14 hour period...

"The wind was reported at 75 miles an hour."

A-4. HURRICANE TRACKS

The tracks of four notable hurricanes causing tidal flooding and serious damages along the Connecticut coast, namely, those of September 1815, September 1938, September 1944, and August 1954 are shown on Plate A-1. The path of Hurricane "Diane" (1955), a storm which brought record rainfall to many areas in southern New England, is also shown on the plate.

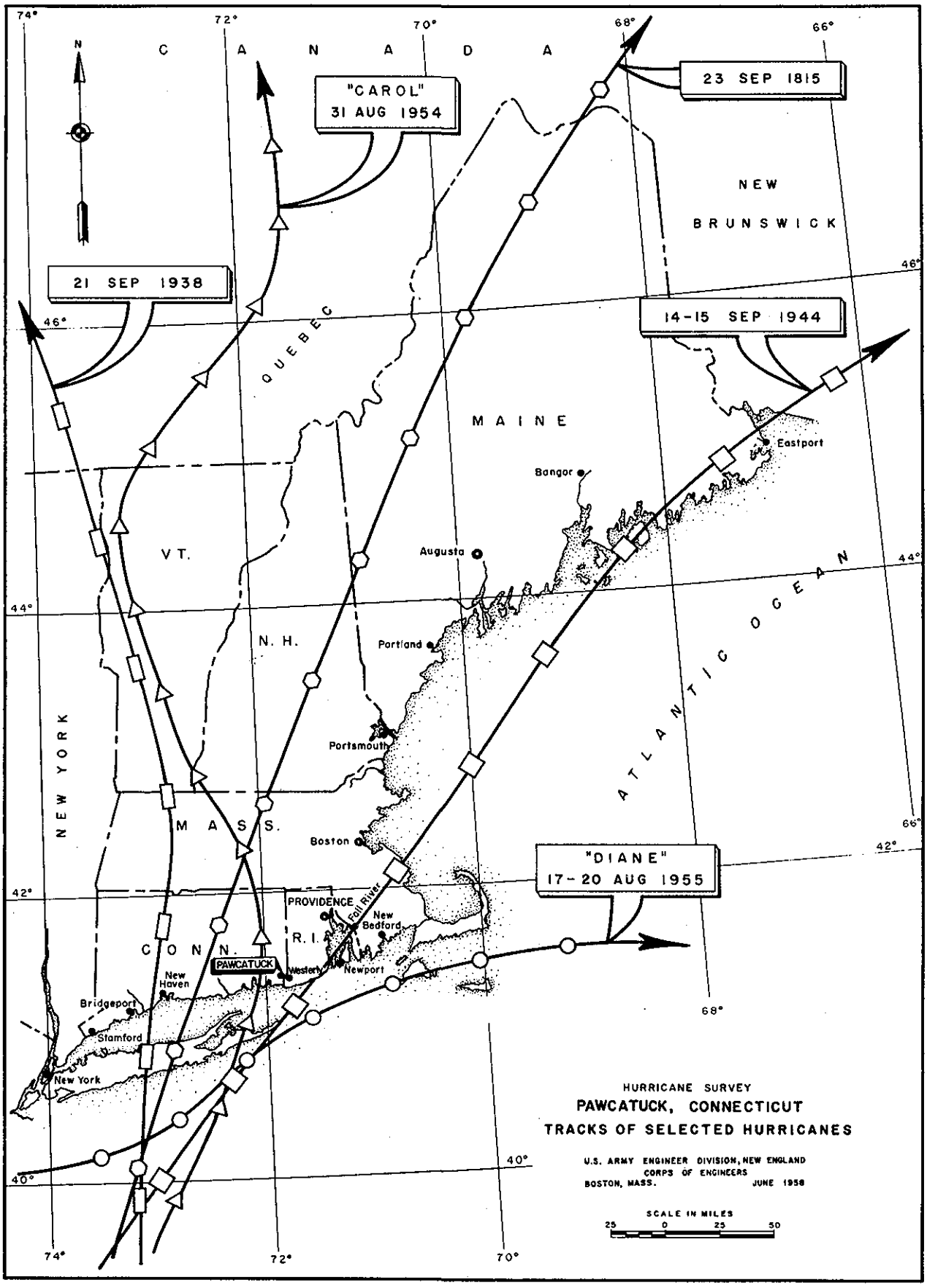

"CAROL"
31 AUG 1954
23 SEP 1815
21 SEP 1938
14-15 SEP 1944
"DIANE"
17-20 AUG 1955
CANADA
NEW BRUNSWICK
QUEBEC
MAINE
VT.
N. H.
MASS.
CONN.
R.I.
NEW YORK
ATLANTIC OCEAN
Eastport
Bangor
Augusta
Portland
Portsmouth
Boston
PROVIDENCE
Fall River
New Bedford
Newport
Westerly
PAWCATUCK
New Haven
Bridgeport
Stamford
New York
74°
72°
70°
68°
66°
46°
44°
42°
40°
N
HURRICANE SURVEY
PAWCATUCK, CONNECTICUT
TRACKS OF SELECTED HURRICANES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.
JUNE 1958
SCALE IN MILES
25 0 25 50

PLATE A-I

APPENDIX B

HYDROLOGY AND HYDRAULICS

APPENDIX B

HYDROLOGY AND HYDRAULICS

INTRODUCTION

B-1. This appendix presents data to supplement the sections of the main report relating to the subjects of hydrology and hydraulics. It includes a summary of temperature and precipitation data to amplify the section of the report on "Climatology", a summary of streamflow data on hurricane wind velocities, rainfall values, and barometric pressures to augment report material on the history and frequency of hurricanes. Determination of flood levels and design storm tide are also included in this appendix.

HYDROLOGY

B-2. TEMPERATURE AND PRECIPITATION

The variable and temperate climate of the Pawcatuck area is influenced by several meteorological factors which produce extremes of temperature and precipitation. The area lies in the path of the "prevailing westerlies" and the cyclonic disturbances that cross the country from the west and southwest. It is also exposed to occasional coastal storms that move up the Atlantic seaboard, some of which are of tropical origin. Significant temperature and precipitation data taken from the United States Weather Bureau Station at New London, Connecticut has been applied to the Pawcatuck area, a distance of approximately 14 miles to the west. The monthly mean temperatures are based on the period of record from 1871 to 1954, while the maximum and minimum temperatures are based on the period 1885 to 1954. The monthly mean, maximum and minimum precipitation is based on an 84-year record (1871-1954). Tables B-1 and B-2 summarize the temperature and precipitation records.

B-3. RUNOFF AND STREAMFLOW

Records of streamflow at three locations in the Pawcatuck River basin have been obtained by the U. S. Geological Survey for various periods of time since December 1939. One of these gages, with a drainage area of 295 square miles, is situated about one mile upstream from the site of the hurricane protection project. A summary of the peak discharges at these three gages is shown in Table B-3.

TABLE B-1

MONTHLY TEMPERATURE

NEW LONDON, CONNECTICUT

Month	Degrees Fahrenheit Mean	Maximum	Minimum
Jan.	29.8	67	- 7
Feb.	29.8	68	-17(1)
Mar.	37.4	84	3
Apr.	46.9	91	13
May	57.4	93	31
June	66.2	97	38
July	71.7	99	44
Aug.	70.3	100(2)	44
Sept.	64.4	95	35
Oct.	54.3	87	24
Nov.	43.4	77	9
Dec.	33.0	67	-12

Annual 50.4

(1) 9 Feb. 1934
(2) 26 Aug. 1948

TABLE B-2

MONTHLY PRECIPITATION

NEW LONDON, CONNECTICUT

Month	Inches Mean	Maximum	Minimum
Jan.	4.04	8.61	0.50
Feb.	3.62	11.98	.43
Mar.	4.20	10.96	.35
Apr.	3.76	10.85	.64
May	3.49	9.03	.54
June	3.09	7.71	.01(1)
July	3.53	7.13	.44
Aug.	4.39	16.44(2)	.48
Sept.	3.41	11.21	.33
Oct.	3.52	8.47	.20
Nov.	3.83	9.40	.32
Dec.	3.77	10.67	.73
Annual	44.61	60.62(3)	30.05(4)

(1) 1949
(2) 1874
(3) 1919
(4) 1896

TABLE B-3

STREAMFLOW DATA

PAWCATUCK RIVER BASIN

River and Location	Drainage Area (sq.mi.)	Period of Record (years)	Peak Discharge (cfs)	(cfm)(1)	Date
Pawcatuck River at Wood River Jct., R. I.	100	15	1,040	10.4	17 Mar. 1953
Wood River at Hope Valley, R. I.	72.4	14	1,470	20.3	12 Sept. 1954
Pawcatuck River at Westerly, R. I.	295	15	3,510(2)	11.9	16 Mar. 1953

(1) Cubic feet per second per square mile
(2) Maximum estimated discharge of 3,800 cfs occurred in February 1886, November 1927, and September 1932.

B-4. DESCRIPTION OF PAWCATUCK RIVER BASIN

The Pawcatuck River has a total drainage area of 303 square miles, of which approximately 246 square miles are in Rhode Island, and 57 square miles are in Connecticut. The lower ten miles of the river forms the boundary between the two states. The river has a total fall of 90 feet and is tidal and navigable from the mouth to Westerly, Rhode Island, a distance of about five miles.

B-5. HURRICANE RAINFALL

Among the greatest rainfalls associated with hurricanes in New England are those recorded for "Connie" and "Diane" in August 1955. Hurricane "Connie", 11-15 August, caused rainfall varying from about four to six inches over southern New England and ended a period of drought. A week later, on 17-20 August, Hurricane "Diane" brought rainfall of 16 to 20 inches over Connecticut and Massachusetts. Although Pawcatuck did not receive excessive rainfall in either of these storms, they caused a total fall of 7.95 inches at Groton, Connecticut, 12 miles west of Pawcatuck, and 8.9 inches at Kingston, Rhode Island, 18 miles to the northeast.

Excessive rainfall also was associated with the September 1938 hurricane. The maximum precipitation for the September 1938 storm was concentrated over Portland (Buck), Connecticut, about one mile north of Middletown, where a total of 17 inches was recorded for the period 17-21 September. At Kingston, Rhode Island, the total was 2.8 inches and at New Haven, Connecticut, 50 miles west of Pawcatuck, the total was 11.6 inches.

The recorded rainfall at five U. S. Weather Bureau stations near Pawcatuck in a number of recent hurricanes are tabulated in Table B-4, and may be considered indicative of amounts that have occurred in the Pawcatuck area. Other notable storms occurred in 1886, 1927 and 1932. From 11 to 13 February 1886 over 8 inches of rainfall occurred in southeastern Connecticut and in Rhode Island melting a snow cover of 6 to 7 inches. Westerly, Rhode Island had 9.12 inches of rain in 12 hours on 3 and 4 November 1927, and 12.13 inches in 20 hours on 16 September 1932.

B-6. HURRICANE WINDS

The most reliable data on experienced hurricane wind velocities in New England begin with the September 1938 hurricane. The maximum velocity in New England during this storm was a recorded gust of 186 m.p.h. at the Blue Hill Observatory in Milton, Massachusetts where a sustained 5-minute wind of 121 m.p.h. was also recorded. At other locations in southern New England, sustained 5-minute velocities ranging from 38 to 87 m.p.h. were experienced.

Sustained 5-minute velocities of 33 to 85 m.p.h. were recorded at a number of locations along the New England coast during the hurricane of 14 September 1944. An estimated maximum gust of 109 m.p.h. occurred at Hartford, Connecticut.

In southern New England, during Hurricane "Carol", 31 August 1954, gusts of 125 and 130 m.p.h. were experienced at Milton, Massachusetts and Block Island, Rhode Island, respectively. Sustained 1-minute velocities ranging from 38 to 93 m.p.h. were registered.

Recorded wind velocities at locations in southern New England for the three great hurricanes of 1938, 1944, and 1954, are given in Table B-5.

B-7. HURRICANE BAROMETRIC PRESSURES

The center, or "eye" of the 1938 hurricane entered Connecticut about 5 miles west of New Haven at about 3:30 P.M., E.S.T., on 21 September and then proceeded northwesterly at a rate of 50 to 60 m.p.h. The lowest pressure registered during the passage of this storm was 28.04 inches at Hartford, Connecticut.

TABLE B-4

HURRICANE AND OTHER STORM RAINFALL

CONNECTICUT AND RHODE ISLAND

ACCUMULATED RAINFALL IN INCHES

Hurricane or Other Storm	New Haven, Conn.		Westbrook, Conn.		New London, Conn.		Groton, Conn.		Kingston, R. I.	
	Max. 24-hr.	Storm Total	Max. (1) 24-hr.	Storm Total	Max.(1) 24-hr.	Storm Total	Max.(1) 24-hr.	Storm Total	Max. 24-hr.	Storm Total
Sept. 1938	6.4	11.6	-	-	-	-	-	-	1.3	2.8
Sept. 1944	4.0	8.5	2.8	6.2	3.4	7.1	-	-	2.4	4.4
Aug. 1954 (Carol)	2.75	2.75	4.4	4.4	4.5	5.0	3.4	3.5	2.9(1)	2.9
Sept. 1954 (Edna)	5.55	5.55	5.6	5.6	4.0	5.3	6.2	6.2	5.5(1)	5.5
Aug. 1955 (Connie)	3.2	3.6	4.3	7.3	2.0	4.0	5.1	5.6	5.3(1)	5.7
Aug. 1955 (Diane)	3.2	4.3	1.4	2.2	1.8	1.8	1.2	2.3	2.2(1)	3.2
Oct. 1955	3.8	5.9	-	5.1	-	-	2.3	4.3	3.1(1)	4.65

(1) Non-recording station - values based on daily readings.

TABLE B-5

MAXIMUM WINDS

HURRICANES OF 1938, 1944 AND 1954 IN NEW ENGLAND

Location	Velocity in Miles Per Hour: Sustained 5-Min.	Sustained 1-Min.	Maximum Gust	Direction
	Hurricane of 21 September 1938			
Hartford, Conn.	46	-	59	NE
New Haven, Conn.	38	-	46	NE
Providence, R. I.	87	-	95	SW
Block Island, R.I.	82	-	91	SE
Milton, Mass. (Blue Hill Observatory)	121	-	186	S
	Hurricane of 14 September 1944			
New Haven, Conn.	33	38	65	N to NE
Hartford, Conn.	50	62	109(est)	N
Block Island, R. I.	82	88	100+	SE
Chatham, Mass.	-	85	100(est)	-
Point Judith, R. I.	85(est)	90(est)	-	SSE
Milton, Mass. (Blue Hill Observatory)	67	77	-	
	Hurricane of 31 August 1954, "Carol"			
Bridgeport, Conn.	-	-	60	-
New Haven, Conn.	-	38	65	N
Hartford, Conn.	-	56	64	NE
Block Island, R. I.	-	98	135	SE
Milton, Mass. (Blue Hill Observatory)	-	93	125	SE

In the hurricane of 14 September 1944, the "eye" of the storm passed inland between Charlestown and Point Judith, Rhode Island, (15 miles east of Pawcatuck) at 10:20 P.M., E.S.T. It then continued in a northeasterly direction veering out to sea at Boston, Massachusetts. The minimum recorded barometric pressure in southern New England during this storm was 28.31 inches at Point Judith, Rhode Island.

The center of Hurricane "Carol", 31 August 1954, crossed the south shore of Connecticut in the vicinity of New London (14 miles west of Pawcatuck) at about 10:30 A.M., E.S.T., and then followed a general northwesterly path across New England. The minimum barometric pressures in New England upon the occasion of this hurricane were 28.20 inches at Storrs, Connecticut (35 miles northwest of Pawcatuck), and 28.26 inches at New London.

The minimum pressures recorded at a number of New England locations during these three great hurricanes of the past 20 years are given in Table B-6.

B-8. DESCRIPTION OF PROJECT AREA

The area selected for detailed study under the Pawcatuck local protection plan consists of 39 acres of industrial and residential properties, on the west bank of the Pawcatuck River. (See Plate E-1.) It is bounded on the east by the river, and on the west by the railroad embankment of the New York, New Haven, and Hartford Railroad. The proposed dike and wall will inclose the area on the north and east, and the spur track embankment which enters the Cottrell property will complete the closure on the south.

The land containing the Bostitch and Cottrell plants, east of Mechanic Street, comprises slightly more than half the drainage area. It is comparatively flat, with slopes varying from one foot to six feet between the street and the river bank. The Bostitch property is mostly paved, whereas the Cottrell section is almost completely unpaved and much of it cinder fill. West of Mechanic Street the land rises steeply from an elevation of 6 to 12 feet, m.s.l., to approximately 30 feet, m.s.l., along the railroad embankment. Both Cedar Street and Palmer Street drop sharply an average of 18 feet in 300 feet from Prospect Street toward Mechanic Street.

B-9. DESIGN RAINFALL

The design rainfalls for local drainage of 3.2 inches in an hour for one area and 3.9 inches in an hour for another area were selected for the project area based on data contained in the U. S. Department of Agriculture Publication No. 204, "Rainfall Intensity-Frequency Data". Records of precipitation are not available in the immediate vicinity of Pawcatuck to indicate the rainfall intensity that has occurred during recent hurricanes or major storms.

TABLE B-6

MINIMUM BAROMETRIC PRESSURES

HURRICANES OF 1938, 1944 AND 1954 IN NEW ENGLAND

Location	Time (EST)	Barometric Pressure (Inches)
	Hurricane of 21 September 1938	
Hartford, Conn.	4:17 P.M.	28.04
New Haven, Conn.	3:30 P.M.	28.11
Block Island, R. I.	3:05 P.M.	28.66
Milton, Mass. (Blue Hill Observatory)	-	29.01
	Hurricane of 14 September 1944	
Hartford, Conn	9:50 P.M.	28.94
New Haven, Conn	8:50 P.M.	28.86
Westerly, R. I.	9:40 P.M.	28.43
Block Island, R. I.	10:09 P.M.	28.34
Point Judith, R. I.	10:20 P.M.	28.31
Milton, Mass. (Blue Hill Observatory)	-	-
	Hurricane of 31 August 1954	
New Haven, Conn.	9:10 A.M.	28.77
New London, Conn.	10:00 A.M.	28.26
Storrs, Conn.	11:00 A.M.	28.20
Block Island, R. I.	-	28.5
Milton, Mass. (Blue Hill Observatory)	-	29.9

Table B-4, page B-5, however, includes 24-hour amounts and total storm rainfall for the U. S. Weather Bureau stations at New London and Groton, Connecticut, and at Kingston, Rhode Island which are near Pawcatuck. At Westerly, Rhode Island, during the 3-4 November 1927 storm, an independent observer recorded rainfall of 3.15 inches in 4 hours and 15 minutes plus 5.97 inches in the remaining 8 hours of the storm. At other points in southern New England rainfall intensities of four to eight inches in six hours have been recorded during recent hurricanes.

B-10. DESIGN RUNOFF

The design storm runoff for local drainage was based on the Rational Formula (Q=CIA) in which

Q=Runoff, in cubic feet per second

C=Coefficient, representing the ratio of rates of rainfall and runoff

I=Maximum average rainfall intensity, in inches per hour occurring over the entire drainage area during the time of concentration

A=Drainage area, in acres

In determining the maximum required pumping capacity for the 39-acre watershed east of the New York, New Haven and Hartford railroad embankment, the topography and runoff characteristics of the area indicated that two separate flow lines would occur; one from the 18 acres above, and including, the property formerly owned by the Bostitch Company, and the other from the 21 acres of the Cottrell section. The selected values of "C" were 0.6 for the flat but mostly paved Bostitch portion, and 0.4 for the improved Cottrell portion. The rainfall intensities, obtained from the U.S. Department of Agriculture Publication No. 204, were 3.2 and 3.9 inches per hour, respectively.

The computed peak runoff for the Bostitch area was determined to be about 35 c.f.s., and about 33 c.f.s. from the Cottrell area. In addition, some of the runoff from the 55 acres of residential properties west of the railroad will enter the protected area. The largest percentage of the rainfall excess drains into the Pawcatuck River outside the limits of the project, but an estimated 20 percent of the computed peak runoff of 80 c.f.s., or 16 c.f.s., is expected to flow into the Bostitch area. However, with a longer distance to travel, this discharge will reach the pumping station after the 68 c.f.s. peak flow from the 39-acre area has arrived. It is estimated that about 10 c.f.s. will be contributed, making the required pumping capacity 78 c.f.s. The adopted design capacity of the pumping station is 40,000 g.p.m., equivalent to 89 c.f.s.

B-11. HURRICANE OR SEVERE STORM FLOOD LEVELS

The heights of tidal flooding experienced at a number of locations in the Groton-Stonington-Pawcatuck area during Hurricane "Carol" (1954) were obtained in the course of the field damage-survey work for the southern New England coastline. The elevation of these flood levels, referred to mean sea level, were then determined by a field level party. This information was supplemented by material on high water levels collected by this office after the September 1938 hurricane. Based on this data, profiles have been prepared of the 1938 and 1954 tidal flood elevations between Willetts Point, New York at the western end of Long Island Sound, and Wareham, Massachusetts at the eastern end of Buzzards Bay. Maps and profiles for the coastline between the Connecticut River on the west and Point Judith, Rhode Island on the east have been prepared. (See Plates B-1 thru B-4). At the mouth of the Pawcatuck River, mile 110 + 00, a general level in the area is indicated of 10.4 feet, m.s.l. in 1938 and 9.7 feet, m.s.l. in 1954.

High water marks for the Pawcatuck River between the mouth and the U.S. Geological Survey gaging station above Westerly are indicated on Plate B-4. The average elevation for both the 1938 and 1954 tidal floods was about 0.7 foot higher in the vicinity of the Bostitch and Cottrell plants than in the Watch Hill Cove area on the coast.

At Pawcatuck, flooding is caused by a combination of fresh water (river) flow and salt water (tidal) backwater, but flood damage is primarily the result of tidal flooding. Analyses have been made of U.S. Geological Survey recording gage records for the station located about one mile above the local protection project. Backwater curves were determined to provide a relation between elevations at the gage and the project for hydrograph peaks unaffected by tidal backwater. In those cases where tidal surge was the principal factor, the hydrograph peak at the project is approximately the same as at the gage. Usually the tidal surge of a storm produces the higher water mark, and the river runoff produces a somewhat lower peak about one day later.

An illustration of typical flooding at Pawcatuck caused by the combination of fresh water flow and tidal backwater at the U.S. Geological Survey gage for the 1954 Hurricane "Carol" is shown on Plate B-5. Hurricane "Carol", 31 August 1954, caused flooding to elevation 10.4 feet, m.s.l. at both the gage and the project, while the river discharge was rising. The peak river discharge of 1340 c.f.s. occurred one day after the tidal flooding when the river elevation of 4.2 feet, m.s.l. at the gage (2.5 feet, m.s.l. at the project) was unaffected by the tide.

As a contrast to the tidal effect of Hurricane "Carol", Plate B-6 shows the effect of typical fresh water runoff of Hurricane "Edna" 11 days later, on 11 September 1954, when there was no tidal effect.

A discharge of 3340 c.f.s. caused the river to reach an elevation of 7.2 feet, m.s.l., at the gage (5.5 feet, m.s.l., at the project) one day after Hurricane "Edna" passed.

The greatest floods in the Pawcatuck River Basin due to heavy rainfall without the effect of tidal backwater were those of February 1886, November 1927, and September 1932. Accounts of these fresh water floods indicate that the maximum elevation in the vicinity of the local protection project was about 6 feet, m.s.l., or 0.4 feet below zero damage stage.

B-12. STANDARD PROJECT FLOOD (RIVER FLOW)

A Standard Project Flood for the 295 square miles of Pawcatuck River basin was investigated. The discharge hydrographs from the rainfall that accompanied the hurricanes of 31 August 1954 (Carol) and 11 September 1954 (Edna) were used to determine a unit graph of one inch of runoff in seven days having a peak discharge of 2800 c.f.s. Standard Project Storm rainfall of 10.4 inches in 24-hours, derived from Civil Engineer Bulletin No. 52-8 produced 2.6 inches of runoff in seven days based on an assumed factor of rainfall to runoff of 25 percent as compared to the runoff factors of about 15 and 20 percent that occurred from hurricane rainfalls of "Carol" and "Edna", respectively. The runoff factor is low because it represents runoff from the whole basin while the runoff that contributes to the peak discharge in the seven day period presumably comes from the lower 25 percent of the basin that produces about 75 percent of runoff from rainfall. Runoff from the remainder of the basin, influenced by ponds and swamps, is restrained, slow, and well regulated.

The Standard Project Flood estimated from the unit graph and runoff data has a peak discharge of 7800 c.f.s. (26 c.f.s. per square mile) which is equivalent to an elevation of 10.9 feet, m.s.l. The elevation at the project was derived from an extrapolated U. S. Geological Survey rating curve at the gage, a mile above the Bostitch and Cottrell plants, and backwater profiles determined between the gage and mouth of the river. Indications are that the 13 February 1886, 17 September 1932, and 4 November 1927 storms produced the greatest floods known in the Pawcatuck Basin. They were of about equal severity in the vicinity of the local protection project, where elevations of about 6 feet, m.s.l. occurred, equivalent to peak discharge of 3800 c.f.s., (13 c.f.s. per square mile). The Standard Project Flood is twice the discharge of the highest floods of record and 4.9 feet higher in elevation.

If the project were not subject to tidal flooding and was designed only for protection against fresh water flooding, 3 feet of freeboard would be required above the Standard Project Flood elevation placing the top of dikes at elevation 13.9 feet, m.s.l. The top of

dikes adopted for protection against the Standard Project Hurricane, however, is elevation 17.0 feet, m.s.l., (see paragraph E-3, Appendix E), or 3.1 feet higher than required for fresh water flooding.

B-13. DESIGN STORM-TIDE DERIVATION

A memorandum dated 17 May 1957 to the Beach Erosion Board from the Agricultural and Mechanical College of Texas, under contract to make surge calculations of Long Island Sound, is the basis for the design surge for Pawcatuck. The evaluation of Long Island Sound design surge included verification of computations with the observed information on water levels in the Sound during the 1938 hurricane. The wind and pressure pattern utilized for the 1938 hurricane problem was taken from U.S. Weather Bureau Memorandum HUR 7-8, dated 1 June 1956. Storm speeds of the design hurricane were for 30 knots and 40 knots, with the latter condition most critical in the eastern and western portions of the Sound, and the 30-knot speed producing higher surges in the central portion of the Sound. The design hurricane corresponds to a transposition of the 1944 hurricane which was especially severe off Cape Hatteras with the wind field and pressures as specified in U.S. Weather Bureau Memoranda Nos. HUR 7-11 and 7-13, dated 15 June 1956 and 1 August 1956, respectively, and is about equivalent to a Standard Project Hurricane. This storm was considered to move northward along a path that would cause the region of maximum winds and highest surge to be directed into the eastern entrance of the Sound, off Montauk Point, Long Island. At the mouth of the Pawcatuck River, to allow for differences between observed and computed surges in the 1938 hurricane, the computed design surge for the 40-knot storm was modified by the ratio of the observed to the computed 1938 surge. The same ratio also was applied to the 0.7 foot observed difference in 1938 between the mouth of the Pawcatuck River and the project at Pawcatuck. To determine the design stillwater level, the design surge at the mouth of the Pawcatuck River was added to a high spring tide, such as predicted for 24 and 25 September 1957 as shown on Plate B-7, and the differential in level between the river mouth and Pawcatuck. Results for the Pawcatuck local protection project are summarized as follows:

Design storm surge (40-knot speed), feet	13.4
High spring tide, feet, m.s.l.	2.5
Design stillwater level at river mouth	15.9 feet, m.s.l.
Differential, mouth to project, feet	0.8
Design stillwater level at Pawcatuck	16.7 feet, m.s.l.

The ratio of design to 1938 storm surge is approximately 1.4.

B-14. WAVE HEIGHTS

No waves from Long Island Sound would reach Pawcatuck. The area is protected from wave attack by several bends and restrictions in the five miles of river channel making the wind fetch and consequent wave heights at the project negligible.

B-15. ELEVATION-FREQUENCY

Elevation-frequency data, shown in Tables B-7 and B-8 incorporate all information and procedures used in deriving the elevation-frequency curves shown on Plates B-8 and B-9. One set of data is for combined flooding due to both tide and/or river runoff; and the other set is for river runoff, only. The fresh-water frequency curve is based on peak river elevations that usually are not coincident with tidal surge. Available records indicate that fresh-water flooding alone has been limited to elevation 6 feet, m.s.l., 0.4 foot below the beginning of damage. A frequency curve of salt-water flooding alone may be considered essentially the same as the combined flooding curve of Plate B-8, although slightly lower in elevation and nearly parallel.

TABLE B-7

ELEVATIONS VS. FREQUENCY DATA
HURRICANES AND SEVERE STORMS
PAWCATUCK, CONNECTICUT

Hurricane or Storm	Maximum High Water Elevation (ft. m.s.l.)(4)	Percent Chance of Occurrence in any one year (1) (1815-1957)	(Dec. 1940-Nov. 1957)
Hurricane, 21 Sept. 1938	11.1 (2)	0.35	
Hurricane "Carol", 31 Aug. 1954	10.4 (2)	1.05	2.9
Hurricane, 14 Sept. 1944	7.6 (3)		8.8
Storm, 25 Nov. 1950	7.2 (3)		14.7
Storm, 3 Nov. 1951	6.0 (3)		20.6
Storm, 30 Nov. 1944	5.9 (3)		26.5
Storm, 7 Nov. 1953	5.5 (3)		32.4
Storm, 3 Mar. 1942	5.5 (3)		38.2
Hurricane "Edna", 12 Sept. 1954	5.5 (3)		44.1
Storm, 16 Mar. 1953	5.4 (3)		50.0
Storm, 16 Mar. 1956	5.3 (3)		55.9
Storm, 2 Dec. 1942	5.1 (3)		61.8
Storm, 17 Oct. 1955	4.9 (3)		67.6
Storm, 18 Apr. 1954	4.3 (3)		73.5
Storm, 8 Aug. 1946	3.9 (3)		79.4
Storm, 20 Mar. 1948	3.9 (3)		85.3
Storm, 16 Apr. 1953	3.8 (3)		91.2
Storm, 1 June 1948	3.8 (3)		97.1
Storm, 31 Dec. 1942	3.7 (3)		100.0

(1) Calculated plotting position -

$$P = \frac{100(M-0.5)}{Y}$$ where

P= percent chance of occurrence in any one year.
M= number of the event.
Y= number of years of record.

(2) Based on high water marks.
(3) Based on record of U.S.G.S. water-stage recording gage, Pawcatuck River at Westerly, R.I., stage related to the location of the Pawcatuck River Local Protection Project.
(4) The order of magnitude of high water occurrences is based on the record of the gage, which is readable to the nearest one-hundredth of a foot.

TABLE B-8

FRESH WATER ELEVATIONS VS. FREQUENCY DATA

HURRICANES AND SEVERE STORMS

PAWCATUCK, CONNECTICUT

Hurricane or Storm	Maximum High Water Elevation (feet, m.s.l.) (4)		Percent Chance of Occurrence in any one yr.(1) (1886-1957)	(Dec. 1940-Nov. 1957)
Storm, 13 Feb. 1886	6.0	(2)	0.69	
Storm, 4 Nov. 1927	6.0	(2)	2.08	
Storm, 17 Sept. 1932	6.0	(2)	3.47	
Hurricane "Edna", 12 Sept. 1954	5.5	(3)		2.9
Storm, 16 Mar. 1953	5.4	(3)		8.8
Storm, 17 Oct. 1955	4.6	(3)		14.7
Storm, 18 Apr. 1954	4.2	(3)		20.6
Storm, 8 Aug. 1946	3.9	(3)		26.5
Storm, 20 Mar. 1948	3.9	(3)		32.4
Storm, 1 June 1948	3.8	(3)		38.2
Storm, 16 Apr. 1953	3.8	(3)		44.1
Storm, 30 Nov. 1944	3.7	(3)		50.0
Storm, 31 Dec. 1942	3.6	(3)		55.9
Storm, 18 May 1948	3.6	(3)		61.8
Storm, 2 Apr. 1948	3.6	(3)		67.6
Storm, 6 Nov. 1955	3.6	(3)		73.5
Storm, 23 Mar. 1942	3.5	(3)		79.4
Storm, 30 Mar. 1953	3.5	(3)		85.3
Storm, 15 Dec. 1953	3.5	(3)		91.2
Storm, 28 Feb. 1945	3.5	(3)		97.1
Storm, 22 Dec. 1951	3.4	(3)		100.0

(1) Calculated plotting position:-

$P = \frac{100(M-0.5)}{Y}$ where

P= percent chance of occurrence in one year.
M= number of the event.
Y= number of years of record.

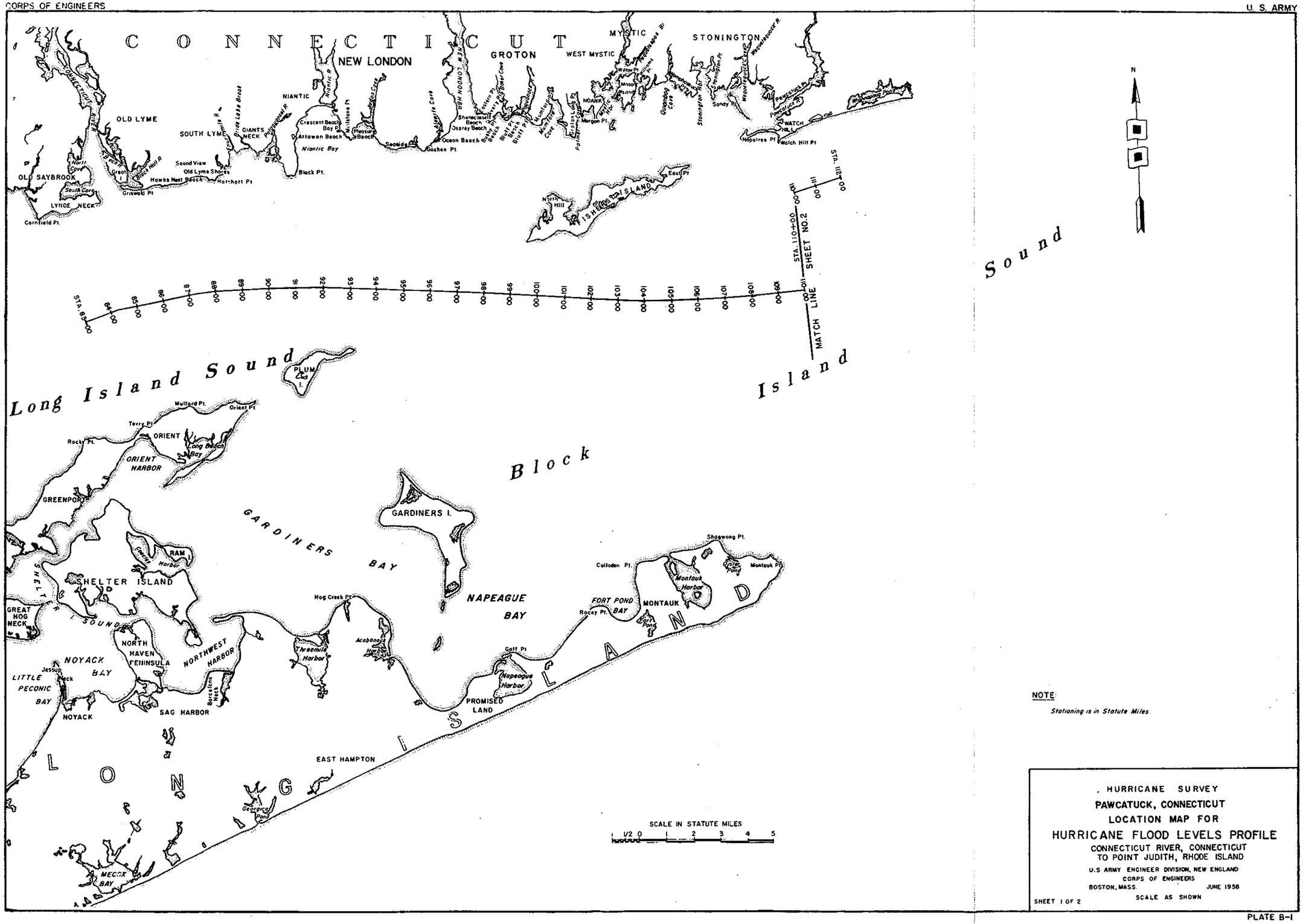
(2) Based on historical accounts.

(3) Based on record of U.S.G.S. water-stage recording gage, Pawcatuck River at Westerly, R. I., stage related to the location of the Pawcatuck River Local Protection Project.

(4) The order of magnitude of most high water occurrences is based on the record of the gage, which is readable to the nearest one-hundredth of a foot.

CORPS OF ENGINEERS

U. S. ARMY



NOTE

Stationing is in Statute Miles

HURRICANE SURVEY

PAWCATUCK, CONNECTICUT

LOCATION MAP FOR

HURRICANE FLOOD LEVELS PROFILE

CONNECTICUT RIVER, CONNECTICUT
TO POINT JUDITH, RHODE ISLAND

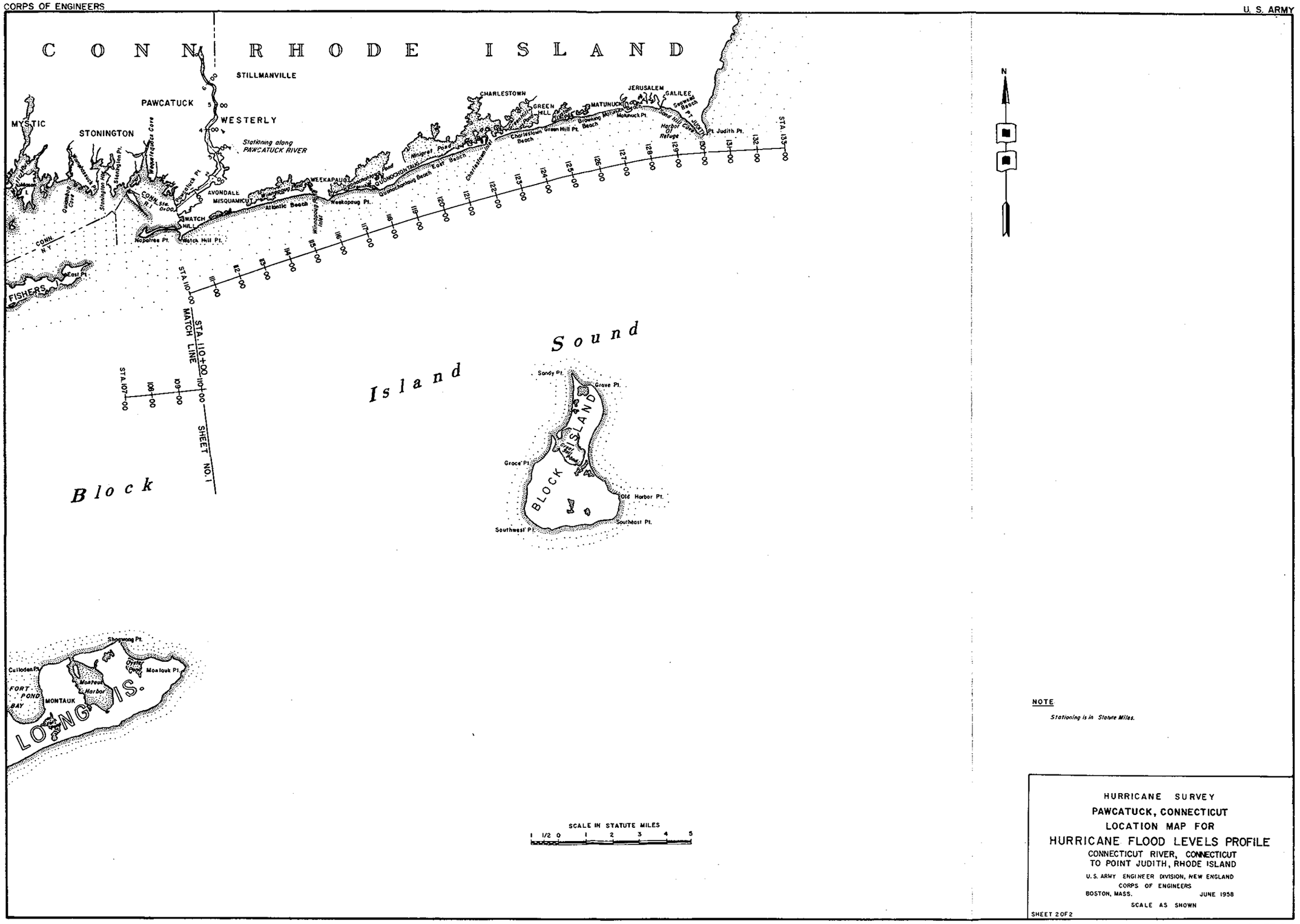
U.S ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. JUNE 1958
SCALE AS SHOWN

SHEET 1 OF 2

PLATE B-1

CORPS OF ENGINEERS

U. S. ARMY



NOTE

Stationing is in Statute Miles.

HURRICANE SURVEY

PAWCATUCK, CONNECTICUT

LOCATION MAP FOR

HURRICANE FLOOD LEVELS PROFILE

CONNECTICUT RIVER, CONNECTICUT
TO POINT JUDITH, RHODE ISLAND

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. JUNE 1958
SCALE AS SHOWN

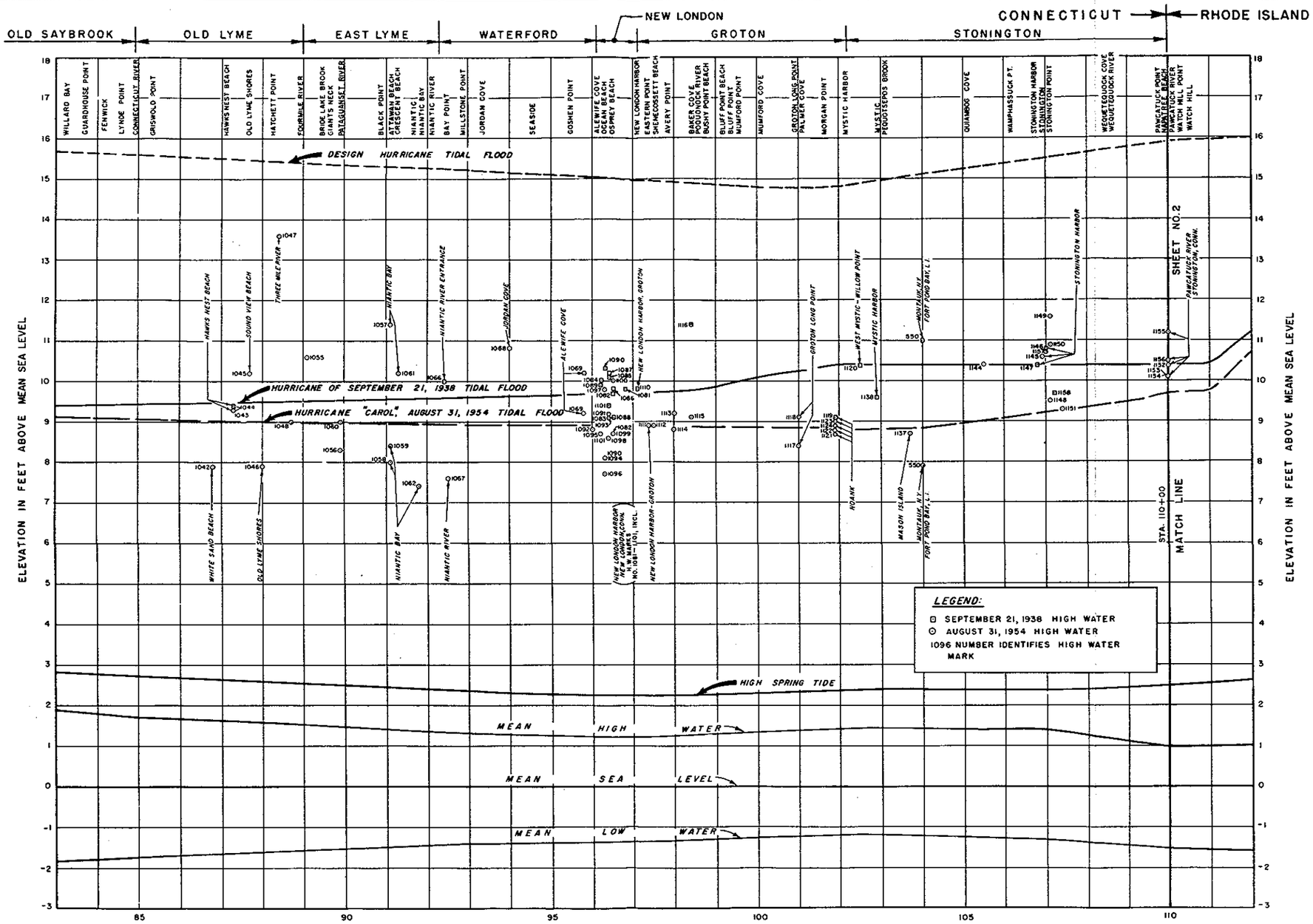
SHEET 2 OF 2

PLATE B-2

CORPS OF ENGINEERS

U.S. ARMY

OLD SAYBROOK | OLD LYME | EAST LYME | WATERFORD | NEW LONDON | GROTON | STONINGTON — CONNECTICUT — RHODE ISLAND



HURRICANE SURVEY

PAWCATUCK, CONNECTICUT

HURRICANE FLOOD LEVELS PROFILE

CONNECTICUT RIVER CONNECTICUT
TO POINT JUDITH, RHODE ISLAND

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. JUNE 1958

SCALE AS SHOWN

SHEET 1 OF 2

PLATE B-3

CORPS OF ENGINEERS

U. S. ARMY

CONNECTICUT — RHODE ISLAND

STONINGTON | WESTERLY | CHARLESTOWN | SOUTH KINGSTOWN | NARRAGANSETT

STONINGTON POINT · WEQUETEQUOCK COVE · WEQUETEQUOCK RIVER · PAWCATUCK POINT · NAPATREE BEACH · PAWCATUCK RIVER · WATCH HILL POINT · WATCH HILL · MISQUAMICUT · ATLANTIC BEACH · WINNAPAUG POND INLET · WEEKAPAUG POINT · WEEKAPAUG · QUONOCHONTAUG BEACH · INLET · QUONOCHONTAUG POND · QUONOCHONTAUG · EAST BEACH · CHARLESTOWN INLET · CHARLESTOWN BEACH · GREEN HILL POINT · GREEN HILL · BROWNING BEACH · MATUNUCK · MATUNUCK POINT · JERUSALEM · GALILEE · HARBOR OF REFUGE · SEAWEED BEACH · POINT JUDITH · NARRAGANSETT PIER

DESIGN HURRICANE TIDAL FLOOD

HURRICANE OF SEPTEMBER 21, 1938 TIDAL FLOOD

HURRICANE "CAROL" AUGUST 31, 1954 TIDAL FLOOD

SHEET NO. 1

MATCH LINE STA. 110+00

HIGH SPRING TIDE

MEAN HIGH WATER

MEAN SEA LEVEL

MEAN LOW WATER

LEGEND:

- □ SEPTEMBER 21, 1938 HIGH WATER.
- ⊙ AUGUST 31, 1954 HIGH WATER.
- 174 NUMBER IDENTIFIES HIGH WATER MARK.

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

STATUTE MILES — BLOCK ISLAND SOUND

110 · 115 · 120 · 125 · 130

HURRICANE SURVEY

PAWCATUCK, CONNECTICUT

HURRICANE FLOOD LEVELS PROFILE

CONNECTICUT RIVER, CONNECTICUT TO POINT JUDITH, RHODE ISLAND

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND, CORPS OF ENGINEERS
BOSTON, MASS. JUNE 1958

SCALE AS SHOWN

SHEET 2 OF 2

PLATE B-4

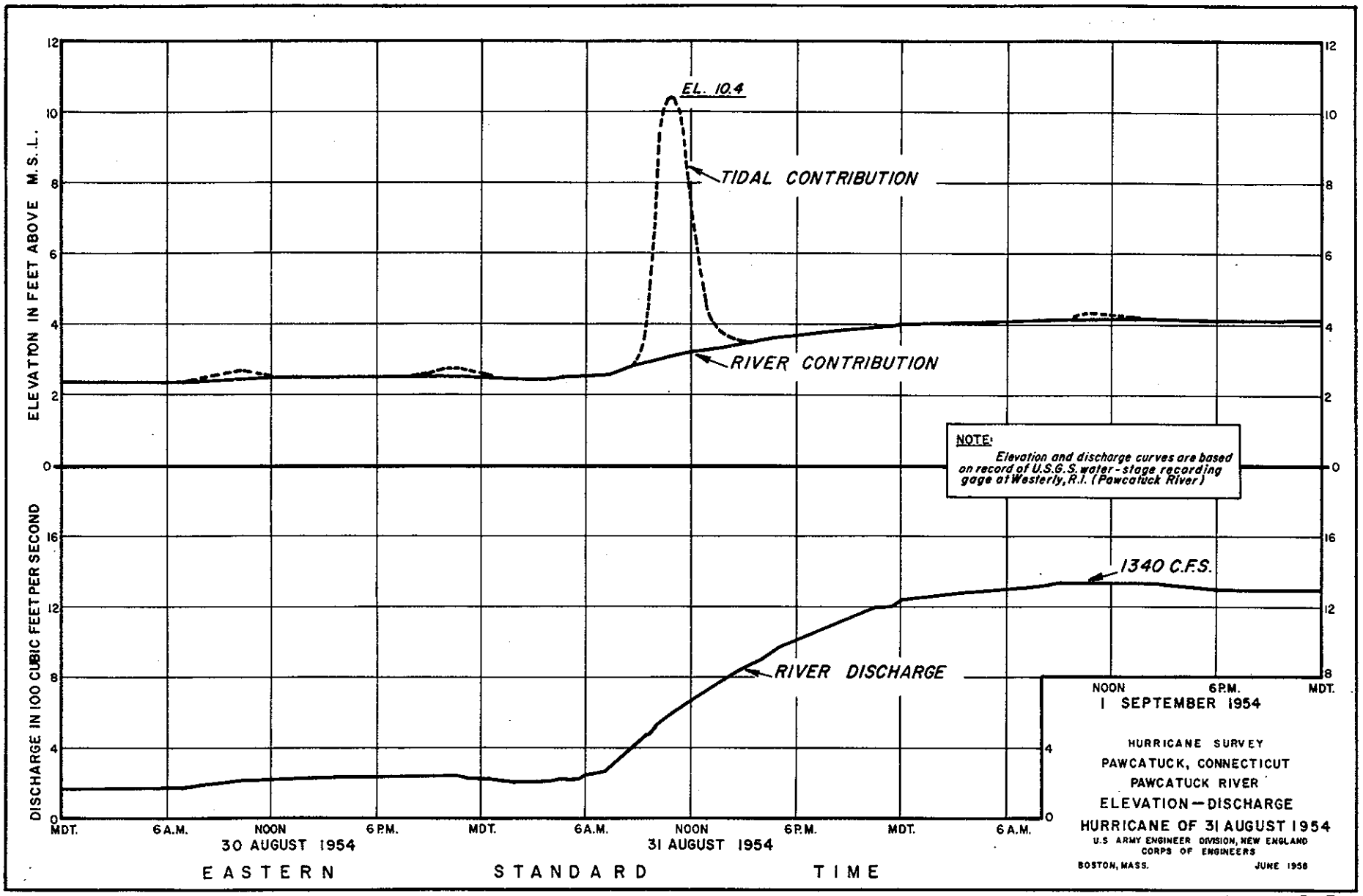

ELEVATION IN FEET ABOVE M.S.L.
DISCHARGE IN 100 CUBIC FEET PER SECOND
EL. 10.4
TIDAL CONTRIBUTION
RIVER CONTRIBUTION
RIVER DISCHARGE
1340 C.F.S.
NOTE:
Elevation and discharge curves are based on record of U.S.G.S. water-stage recording gage at Westerly, R.I. (Pawcatuck River)
MDT. 6 A.M. NOON 6 P.M. MDT. 6 A.M. NOON 6 P.M. MDT. 6 A.M.
30 AUGUST 1954
31 AUGUST 1954
1 SEPTEMBER 1954
NOON 6 P.M. MDT.
EASTERN STANDARD TIME
HURRICANE SURVEY
PAWCATUCK, CONNECTICUT
PAWCATUCK RIVER
ELEVATION — DISCHARGE
HURRICANE OF 31 AUGUST 1954
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.
JUNE 1958

PLATE B-5

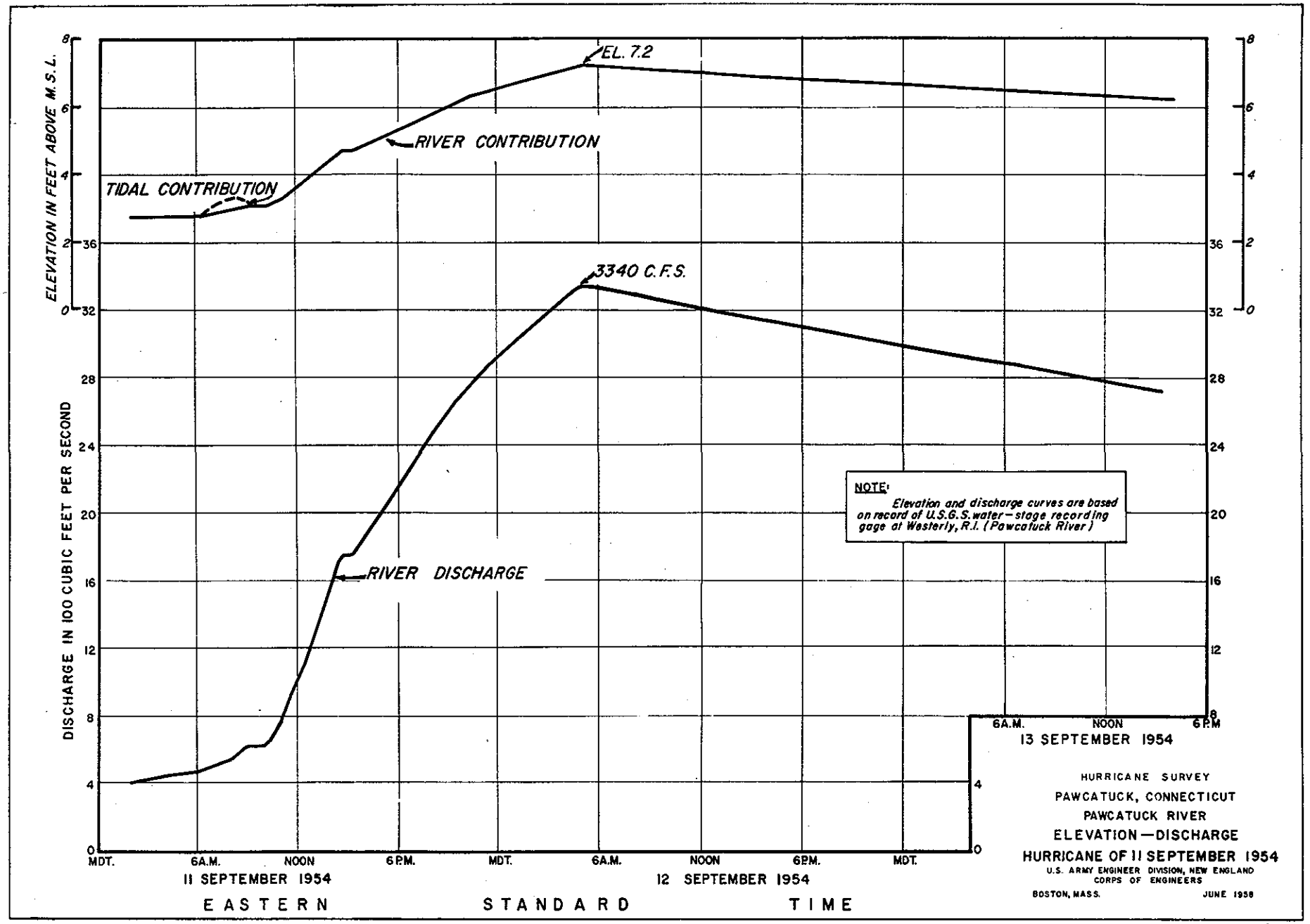
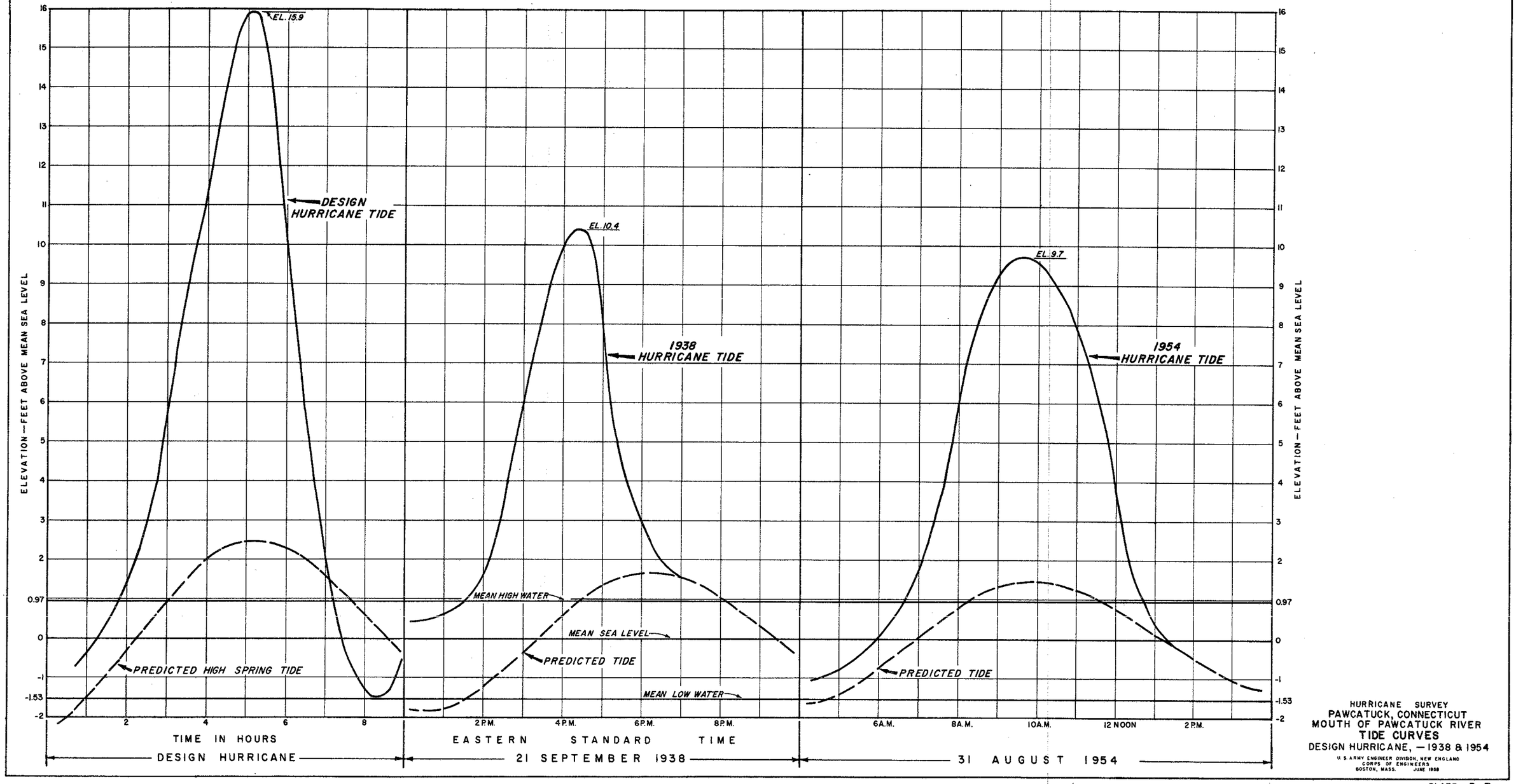

ELEVATION IN FEET ABOVE M.S.L.
DISCHARGE IN 100 CUBIC FEET PER SECOND
EL. 7.2
RIVER CONTRIBUTION
TIDAL CONTRIBUTION
3340 C.F.S.
RIVER DISCHARGE
NOTE:
Elevation and discharge curves are based on record of U.S.G.S. water-stage recording gage at Westerly, R.I. (Pawcatuck River)
MDT.
6A.M.
NOON
6P.M.
MDT.
6A.M.
NOON
6P.M.
MDT.
6A.M.
NOON
6P.M.
11 SEPTEMBER 1954
12 SEPTEMBER 1954
13 SEPTEMBER 1954
EASTERN STANDARD TIME
HURRICANE SURVEY
PAWCATUCK, CONNECTICUT
PAWCATUCK RIVER
ELEVATION—DISCHARGE
HURRICANE OF 11 SEPTEMBER 1954
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.
JUNE 1958

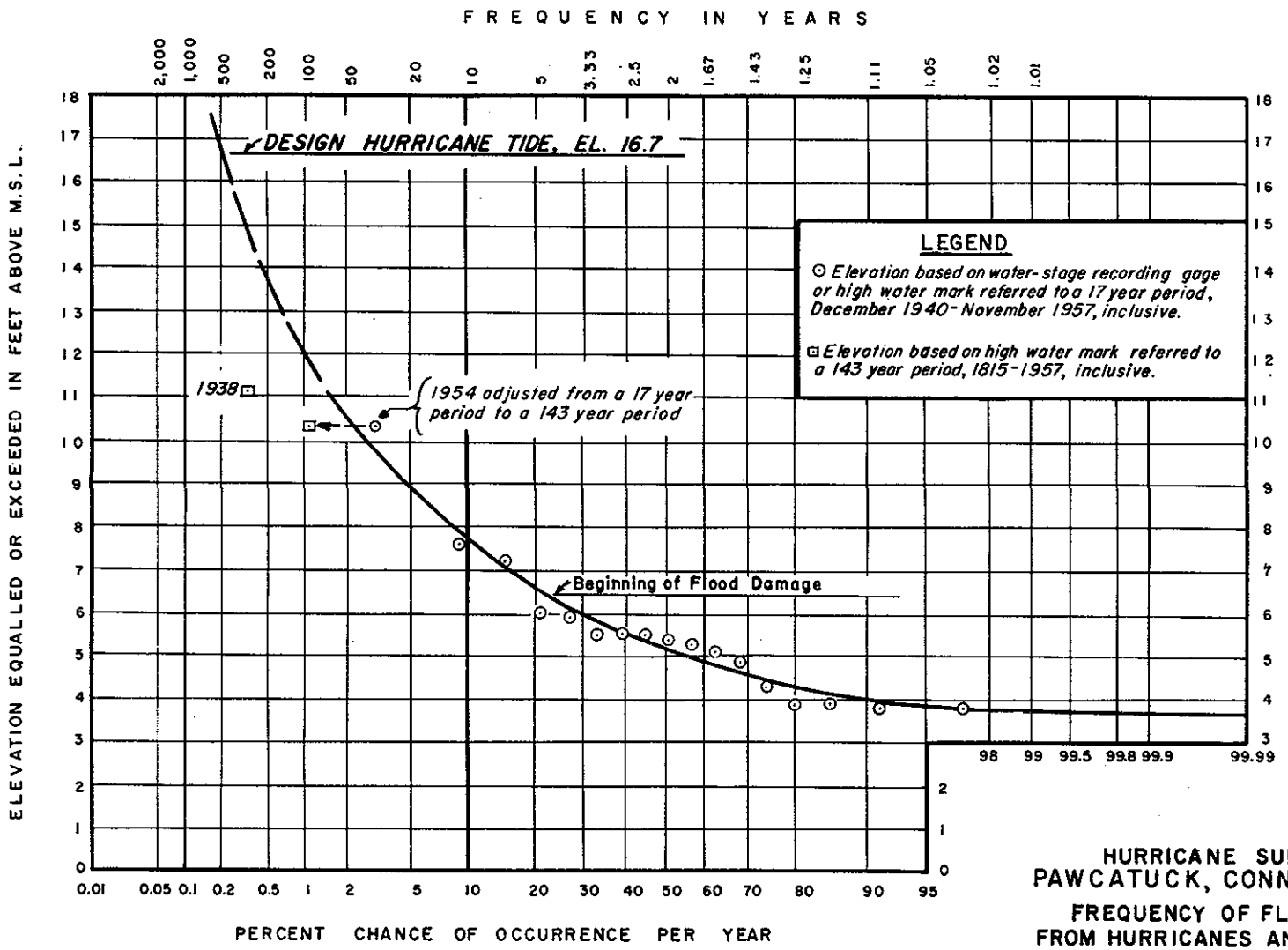
PLATE B-6



HURRICANE SURVEY
PAWCATUCK, CONNECTICUT
MOUTH OF PAWCATUCK RIVER
TIDE CURVES
DESIGN HURRICANE, — 1938 & 1954

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. JUNE 1958

PLATE B-7

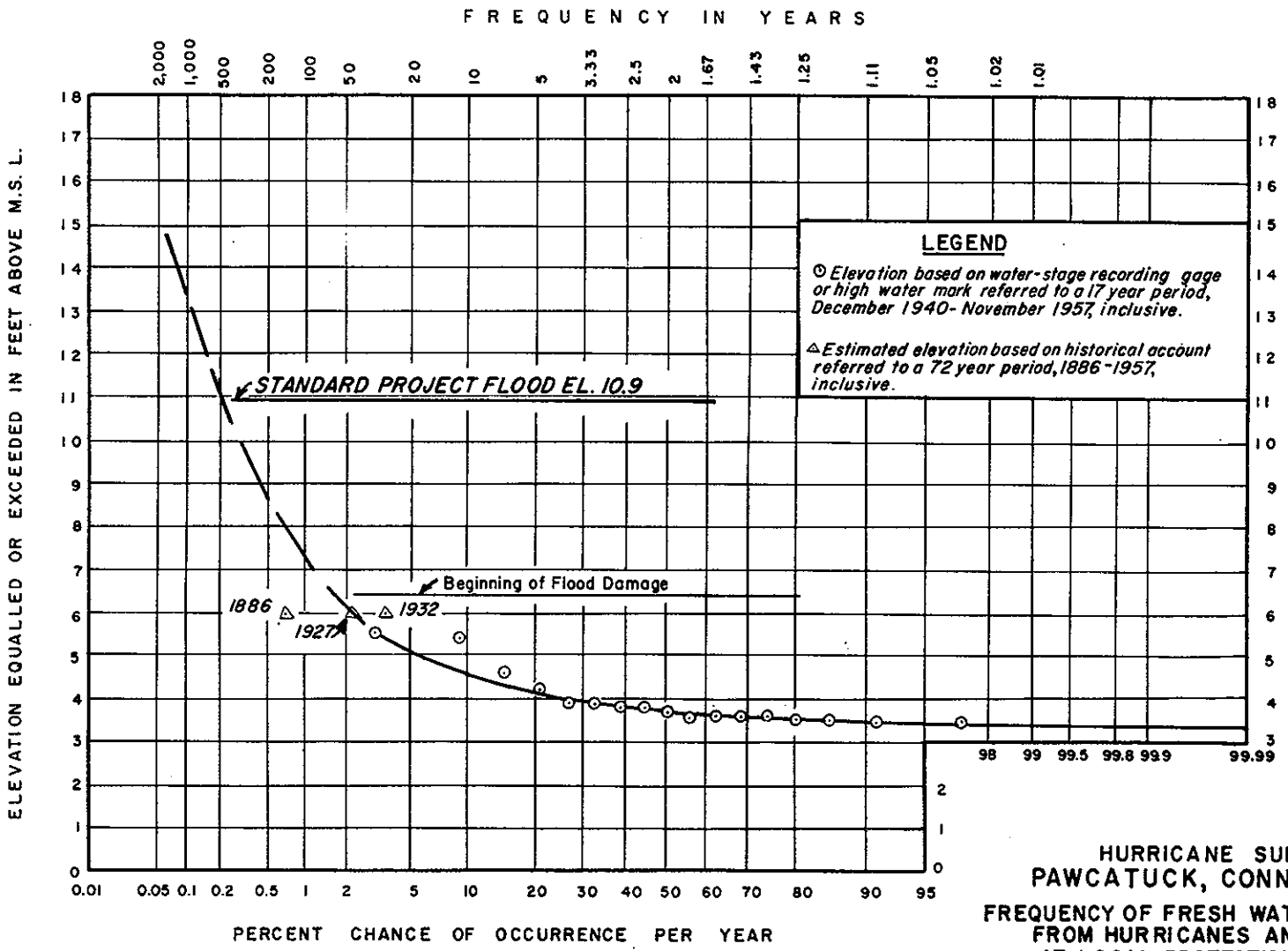


HURRICANE SURVEY
PAWCATUCK, CONNECTICUT

FREQUENCY OF FLOODING
FROM HURRICANES AND STORMS
AT LOCAL PROTECTION PROJECT

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. AUGUST, 1958

PLATE B-8



HURRICANE SURVEY
PAWCATUCK, CONNECTICUT
FREQUENCY OF FRESH WATER FLOODING FROM HURRICANES AND STORMS AT LOCAL PROTECTION PROJECT
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. AUGUST, 1958

PLATE B-9

APPENDIX C

FLOOD LOSSES AND BENEFITS

APPENDIX C

FLOOD LOSSES AND BENEFITS

GENERAL

C-1. *DAMAGE SURVEYS*

Detailed damage surveys were conducted in late 1956 in the tidewater area of the Pawcatuck River. Door-to-door interviews and inspections of the residential, commercial, industrial and other properties affected by tidal flooding were made in the Stonington (Connecticut) and Westerly (Rhode Island) areas extending from Wequetequock Cove and Watch Hill Point, respectively, to the head of tidewater on the Pawcatuck River upstream of the urban centers of Pawcatuck and Westerly. This data included the extent of areas flooded, descriptions of properties including economic and physical changes since the August 1954 hurricane, the nature and amount of damages, depths of flooding, high-water references, and relationships between August 1954 and other flood stages. Damage evaluations were generally furnished by tenants or property owners. Investigators used their own judgement in modifying these estimates and also made estimates where owner or tenant estimates were not available. Sampling methods were often used where properties of the same general type were subject to the same depth of flooding. Data on damages to public property, highways, utilities and railroads were obtained from central sources and applied to the field information.

Sufficient data were obtained to derive losses at the August 1954 flood stage, a stage 3 feet higher and the stage at which damage begins referenced to the August 1954 flood stage. Losses were also determined for intermediate stages where marked increases in damage occurred.

C-2. LOSS CLASSIFICATION

The types of flood losses recorded and indexed as to location include urban (residential, commercial and public), rural, industrial, utility, highway and railroad.

Tangible, primary losses were evaluated. Primary losses comprise the following: (1) physical losses, such as damage to structures, machinery and stock, and cost of cleanup and repairs; and non-physical losses, such as unrecovered losses of business, wages or production, cost of temporary facilities, increased cost of operation or increased cost of shipments within the inundated areas.

The primary loss resulting from physical damage, and a large part of the related non-physical loss, were determined by direct inspection of flooded properties and evaluation by property owners, field investigators or both. The non-physical portions of the primary loss were often difficult to estimate on the basis of available information. Where this condition existed, the non-physical losses were estimated by utilizing determined relationships between physical and non-physical losses for similar properties in the survey area and other areas.

No monetary evaluations were made of secondary or intangible losses. Secondary damages, those incurred outside the immediate flooded area under study, include such items as increased cost of travel and shipment of goods, loss of utilities and transportation facilities, and business losses. Intangible losses include such items as loss of life, hazards to health and detrimental effects on the national security.

HURRICANE TIDAL-FLOOD DAMAGES

C-3. TYPE AND DISTRIBUTION OF TIDAL-FLOOD LOSSES

Serious losses were experienced in the Pawcatuck River area from tidal flooding which accompanied Hurricane "Carol" on 31 August 1954. Tidal flooding on the Pawcatuck River caused total damages of about $1,910,000 when the August 1954 flood stage rose 10.4 feet above mean sea level in the Pawcatuck-Westerly area, reaching a level 0.7 feet below the record flood stage experienced in 1938. Over 250 structures suffered flood damage, including some 115 dwellings, 128 commercial establishments, 5 industrial plants, and other public buildings and piers. A tabulation of 1954 experienced tidal-flood losses in the Pawcatuck River area is shown in Table C-1 by damage areas and by types of losses.

Residential losses accounted for the bulk of the $50,000 loss in Area I, the southeastern section of Stonington extending from Wequetequock Cove to Clarks Village. Fifteen homes located along the numerous coves indenting the right bank of the Pawcatuck River were damaged by tidal flooding, of which 3 homes experienced up to 2 feet of flooding on the first floors.

In the village of Pawcatuck, Area II, losses to two large industrial plants in the Mechanic Street section amounted to about $820,000. Major damage to raw materials and machinery resulted when up to 5 feet of water entered the main floor of the Bostitch plant and nearly 1 foot of water flooded the first floor of the Cottrell firm. Forty-nine commercial firms in the business district downstream of the New York, New Haven and Hartford Railroad bridge sustained about 90 percent of the $215,000 urban loss in Pawcatuck.

TABLE C-1

EXPERIENCED TIDAL-FLOOD LOSSES IN PAWCATUCK RIVER AREA

HURRICANE "CAROL", 31 AUGUST 1954

Pawcatuck (Stonington), Connecticut, and Westerly, Rhode Island

Area	Description	Losses in Thousands of Dollars					
		Urban	Rural	Industrial	Utility	Highway	Total
I	Stonington Area between Wequetequock Cove and Pawcatuck River bend immediately down-stream of Pawcatuck-Westerly urban area	40	5	---	5	(1)	50
II	Pawcatuck Area between river bend and head of tidewater on Pawcatuck River	215	---	820	(1)	5	1,040
III	Westerly Area between head of tidewater and river bend on Pawcatuck River	175	---	20	15	10	220
IV	Westerly Area between Pawcatuck River bend and Watch Hill Point	575	---	---	10	15	600

(1) Highway and utility losses in Areas I and II total $5,000, respectively.

Damage to some 12 dwellings and 24 commercial establishments in the Westerly urban concentration near the head of tidewater accounted for approximately 80 percent of $220,000 loss in Area III. Flooding in the Westerly urban area was largely limited to wet grounds and flooded cellars, with 8 commercial establishments reporting water on their main floors. Although up to 4 feet of water covered the main floors of three westerly industrial plants located immediately upstream of the railroad bridge, precautionary measures kept machinery and stock losses to a minimum.

Losses in Area IV, the Avondale-Watch Hill sections of Westerly fronting on the Pawcatuck River, amounted to about $600,000. Damage to beach property, such as summer homes, seasonal commercial establishments, boatyards and yacht clubs, accounted for the bulk of this loss. Substantial losses were experienced in the Watch Hill Cove area, where nearly 35 commercial establishments were flooded at the first-floor level and a beach club on Napatree Beach was washed away.

C-4. RECURRING LOSSES

Stage-loss curves, referenced to peak elevations for the 1954 hurricane flood, have been developed as the basis for economic analysis. Prepared from the data collected in the recent damage surveys, these stage-loss curves afford a means of determining the magnitude of recurring losses at any stage of flooding up to 3 feet above that experienced in 1954. A breakdown of the losses to be anticipated in the area protected by the Pawcatuck local protection plan, in the event of future hurricanes, is shown at 1958 price levels in Table C-2.

TABLE C-2

RECURRING TIDAL-FLOOD LOSSES
IN PAWCATUCK LOCAL PROTECTION PLAN AREA
(1958 Price Level)
PAWCATUCK, CONNECTICUT

Recurring Hurricanes	Flood Stage (feet, msl)	Recurring Losses in Pawcatuck Local Protection Plan Area
21 Sept. 1938	11.1	$ 1,290,000
31 Aug. 1954	10.4	920,000
14 Sept. 1944	7.6	1,000

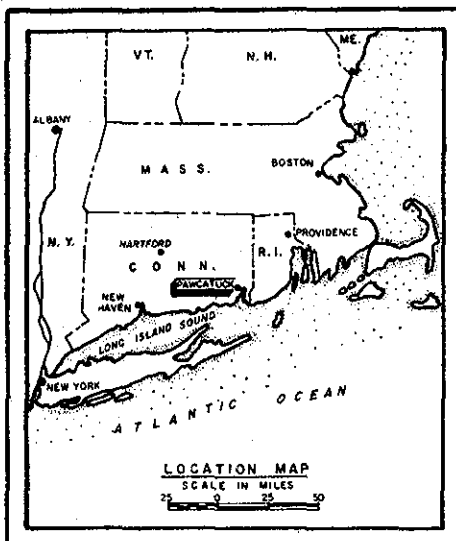
C-5. AVERAGE ANNUAL FLOOD LOSSES

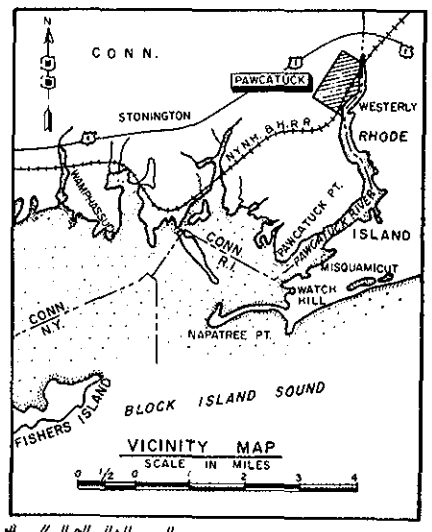
Recurring flood losses in the Pawcatuck local protection plan area have been converted to average annual losses by correlating stage-loss and stage-frequency relationships to derive damage-frequency curves. The stage-frequency curve is based upon the known peak high-water elevations in two recent hurricanes, those of September 1938 and August 1954 (Carol), and on water-stage recording gage records for the period 27 November 1940 to 10 December 1957.

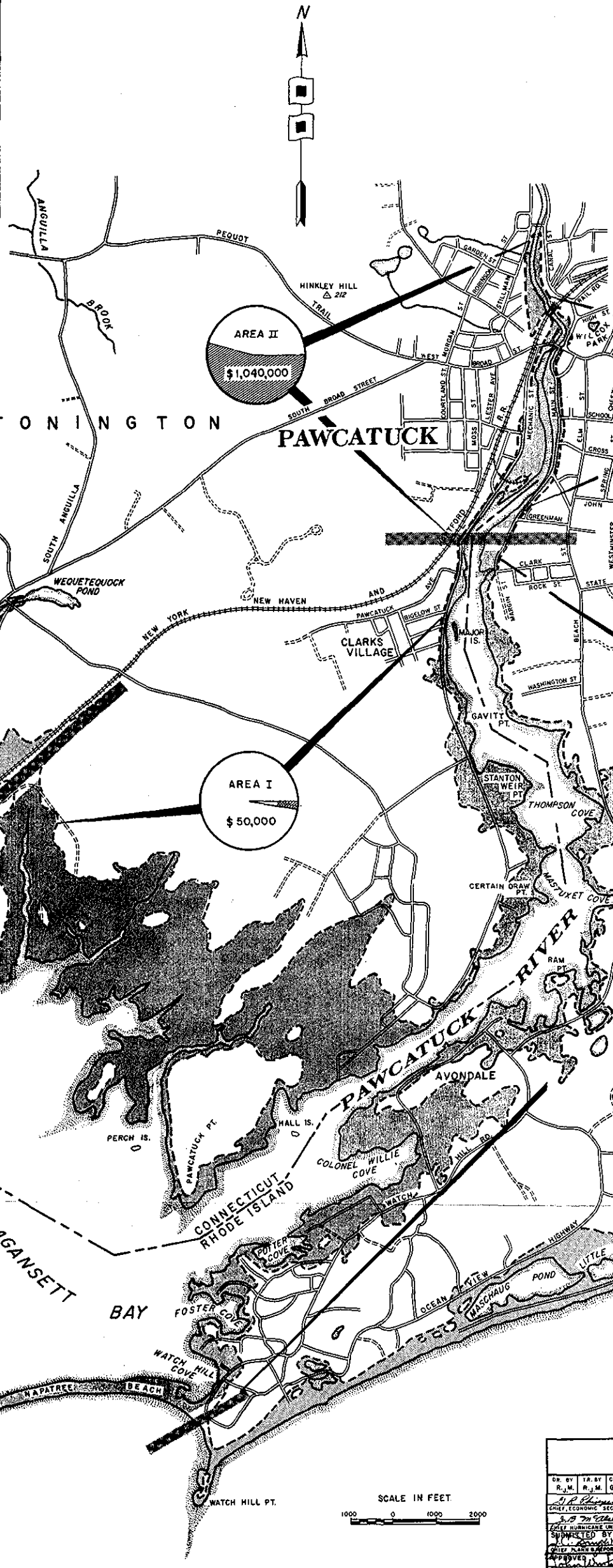
The stage-loss relationship has been combined with the stage-frequency relationship to develop the damage-frequency relationship, which has been plotted with damage as the ordinate and percent-chance-of-occurrence (the reciprocal of frequency) as the abscissa. The area under this damage-frequency curve, see Plate C-2, is a measure of the average annual loss.

C-6. AVERAGE ANNUAL BENEFITS

The total benefits accruing to the plan to control flooding in the Pawcatuck local protection plan area are made up of flood damage prevention benefits and benefits from the elimination of scare costs. Average annual flood damage prevention benefits, by far the most important, have been determined in accordance with standard practices of the Corps of Engineers by utilizing stage-loss and stage-frequency data to develop damage-frequency relationships. The average annual benefits from the prevention of flood damages equal the difference between the average annual losses under present conditions and the average annual losses remaining after the construction of protective works.







LEGEND

- FLOODED AREA 1954 HURRICANE
- DAMAGE AREA LIMITS
- $1,910,000 — TOTAL 1954 TIDAL FLOOD DAMAGES

CORPS OF ENGINEERS U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
R.J.M.	R.J.M.	G.D.B.

CHIEF, ECONOMIC SECTION
CHIEF HURRICANE UNIT
SUBMITTED BY
CHIEF PLANS & REPORT BRAN
APPROVED
CHIEF ENGINEERING DIV.
APPROVED
LT. COL. C.E. ASST. TO DIVISION ENGINEER
DATE JULY 1958

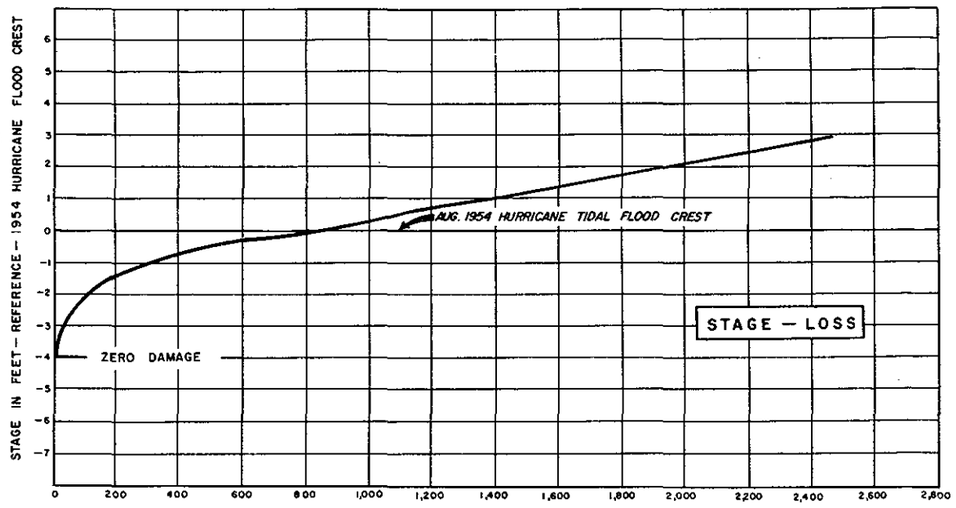
HURRICANE SURVEY
PAWCATUCK CONNECTICUT
FLOOD AREA AND DAMAGES

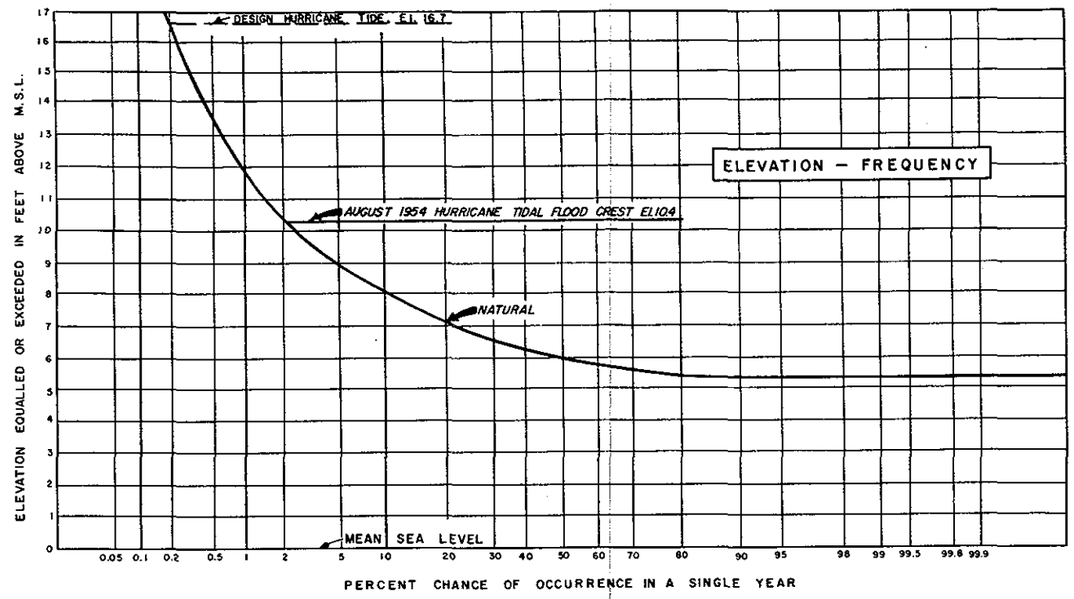
TO ACCOMPANY REPORT
DATED 6 OCTOBER 1958

SCALE AS SHOWN
DRAWING NUMBER
PAC - 4 - 1000
SHEET 1 OF 1

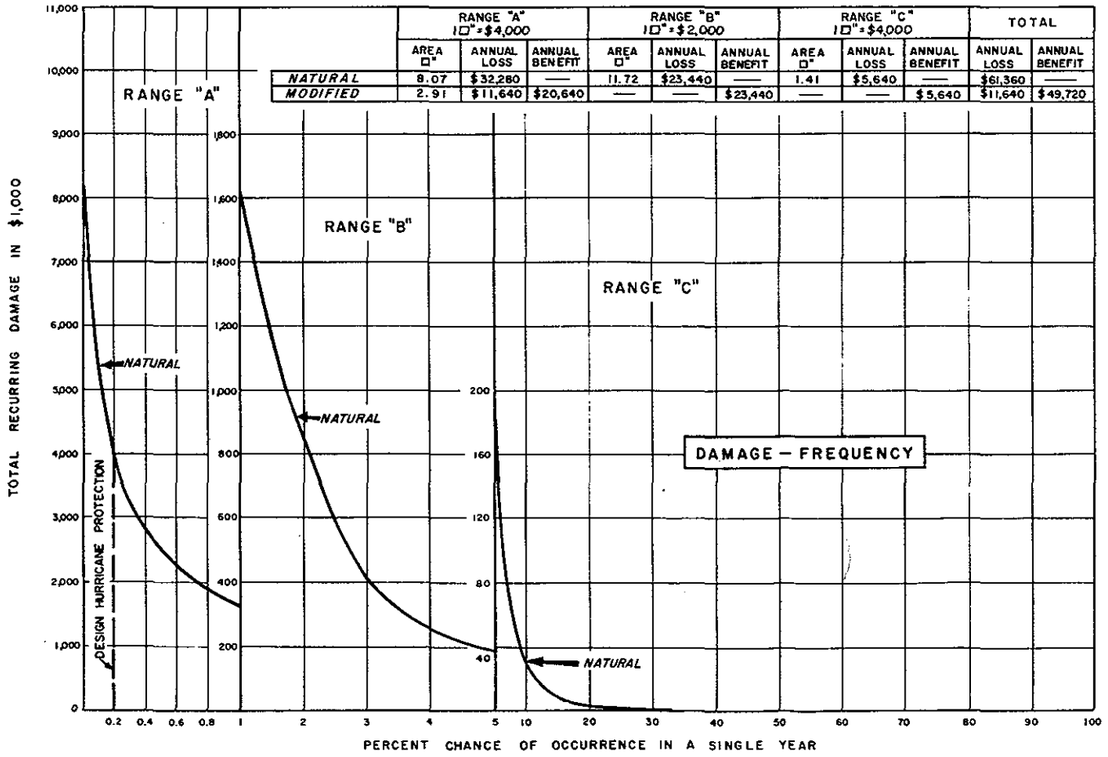
PLATE C-1

PLATE C-1





	RANGE "A" 1D"=$4,000			RANGE "B" 1D"=$2,000			RANGE "C" 1D"=$4,000			TOTAL	
	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	ANNUAL LOSS	ANNUAL BENEFIT
NATURAL	8.07	$32,280	—	11.72	$23,440	—	1.41	$5,640	—	$61,360	—
MODIFIED	2.91	$11,640	$20,640	—	—	$23,440	—	—	$5,640	$11,640	$49,720



HURRICANE SURVEY

PAWCATUCK, CONNECTICUT

CURVES FOR ECONOMIC ANALYSIS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS

BOSTON, MASS. JUNE, 1958

PLATE C-2

APPENDIX D

GEOLOGY AND FOUNDATION DATA

APPENDIX D

GEOLOGY AND FOUNDATION DATA

D-1. GEOLOGY OF THE SITE

The site of the proposed work is located in the southerly portion of a previously existing small temporary glacial lake. The natural soils consist of sandy gravel which overlie till-like silty sandy gravel. Along the present river edge between dike stations 5+05 and 15+40 there exists a wood bulkhead and a concrete wall (see Plate E-2). The river area along this bulkhead has been dredged and the water is about 8 feet deep when the river is at mean sea level. There may exist in the river area a shallow surface deposit of river silt. Industrial waste fill has been placed behind the bulkhead and concrete wall to form a level area between the factory buildings and the river. Fill also exists along the river bank east of the Bostitch Company's building, forming a level parking area. Industrial waste has recently been placed to fill the area south of the railroad spur and east of Mechanic Street at the south end of the factory area.

D-2. SUBSURFACE INVESTIGATIONS

The soil and foundation conditions at the site of the work have been determined, to the extent required for this report, by geological reconnaissance, eight drive-sample borings, and one testpit, and the review of data of three borings made by local interests in connection with a proposed sewer relocation. The locations of all exploration holes and descriptions of the materials encountered are shown on Plate D-1.

D-3. FOUNDATION CONDITIONS FOR CONCRETE STRUCTURE

The proposed concrete land wall and stoplog structure at the north end of the project extends from the fill embankment of the New York, New Haven and Hartford Railroad eastward to just east of Mechanic Street as shown on Plate E-2. According to the subsurface data of boring FD7 and observations in the field, the foundation soil for these structures is natural overburden consisting of gravelly sand. The stoplog structure across Mechanic Street at the south end of the project extends from a railroad fill at the north to a deposit of industrial waste fill at the south. According to available data, the foundation for this structure would be gravelly sand. The foundation elevation for the proposed pumping station at dike station 7+66 is -10.1. Available data indicates that at this elevation, the foundation soils would be entirely gravelly sand. It is considered that the soils forming the foundations for all of these concrete structures would be entirely stable for the imposed loads.

D-4. DIKE FOUNDATION CONDITIONS

The proposed earth dike extends from a waste fill area northward along the edge of the river between station 0+00 and 18+50 and thence northwestward across the existing parking lot to the stoplog structures at Mechanic Street (see Plate E-2). A geologic section taken through the exploration holes is shown on Plate D-1. The abutment at the south end of the dike is an industrial waste fill up to 20 feet thick composed mainly of sand size cinders mixed with fly ash and clinkers, but relatively free of trash. Between station 1 and 5, the foundation soils for the proposed dike are either industrial waste fill or gravelly sand. A portion of the dike foundation area between these stations extends into the river area. From stations 5 to 15, the foundation area for the dike is partly on fill behind the existing bulkhead and partly in the river area. It is expected that the fill is up to 10 feet thick adjacent to the bulkhead and decreases in depth as it extends toward the land side limit of the dike foundation area. According to the available data, the fill material is composed mainly of sand size cinders and fly ash and is quite free of trash. The fill material overlies clean sands and gravels of variable depth which overlie till-like silty sandy gravel. No bedrock was encountered by the exploration holes. At the location of FD3 there exists a layer of soft silt about 3 feet thick between the fill and the underlying original ground. The soils in the foundation area extending into the river between these stations have not been explored. It is expected that these soils consist mainly of gravelly sand similar to the soils encountered in land exploration holes below the fill material. There is a possibility that a thin surface deposit of soft river silt exists in the river area. Between station 15 and 23+86, the soil in the dike foundation area is either natural gravelly sand or fill material overlying natural gravelly sand. The fill material, which probably extends between stations 18 and 23 appears to be mainly sand with a thickness of less than 5 feet. A few holes exist in the parking lot pavement indicating settlement of the fill material. The entire foundation area for the dike is traversed by several drains, sewer and other pipes extending to the river.

D-5. AVAILABILITY OF DIKE MATERIALS

It is considered that the industrial waste material recently placed near the south end of the proposed dike is suitable for impervious fill for the proposed dike. Explorations and observations indicate the waste material to be sand size cinders mixed with fly ash and clinkers but fairly free of trash. Pervious materials and other impervious materials considered suitable for construction of the proposed dike can be obtained from natural deposits within 4 miles of the site. Two major sources of suitable rock fill for the dike exists within 7 miles of the site.

The nearest source which is within 2 miles of the site at Westerly Rhode Island is a quarry dump. To obtain suitable rock fill from this source would require selection and screening. The more distant source is at Bradford,Rhode Island where an active plant is capable of producing all sizes of rock.

D-6. AVAILABILITY OF CONCRETE AGGREGATES.

No investigations were conducted to locate suitable aggregates for concrete as the yardage of concrete for the proposed structures is small. There are commercial sources of suitable aggregates located within an economical distance of the site of the project.

D-7. DESIGN OF DIKE.

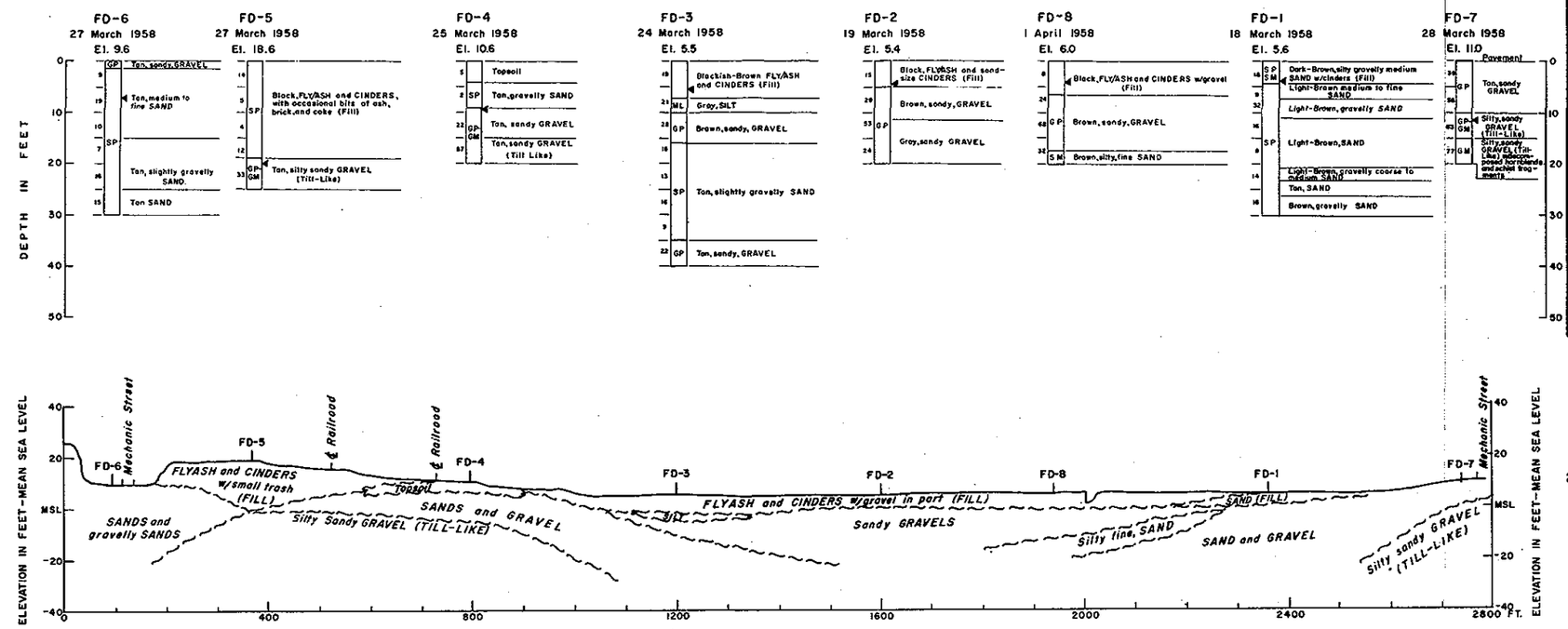
The dike sections and layout (see Plate E-2) were selected on the basis of (a) foundation conditions as described above, (b) the probable characteristics of available earth fill material, and (c) a dike height in general of eight feet. Where the dike foundation area extends into the river, the earth portion of the embankment consists of uncompacted bank run gravel below an elevation sufficient to permit the placement of compacted fill. If constructed, the earth fill portion of the embankment will be composed of both compacted impervious fill and compacted pervious fill. The limits of these two fills will be determined on the basis of availability of materials. The existing wood bulkhead would remain in place. To provide for adequate foundation seepage control, a foundation drain has been provided at the land side toe, extending through the fill material to the underlying sands, and incorporating an interceptor drain pipe. The existing drain pipes, extending to the river in the foundation area, would be plugged and grouted to prevent detrimental foundation seepage. Special construction would be provided to allow settlement of the discharge pipe from the pumping station and to prevent seepage along the pipe. Minimum riprap is provided on the river side slope as the wave height in the adjoining pool would be very small.

D-8. INVESTIGATIONS REQUIRED FOR FINAL DESIGN.

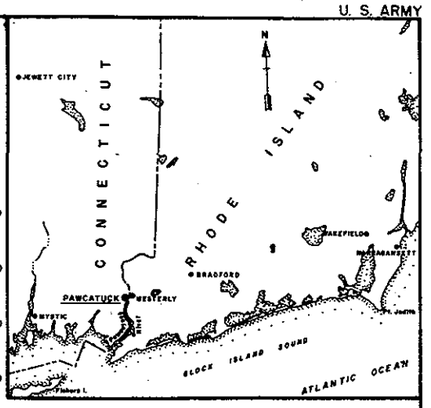
The investigations made to date are of a preliminary nature and should be supplemented to obtain detailed data for the final design of the structures. There appears to be no unusual conditions at the proposed site which will warrant extensive investigations. Prior to final design, detailed subsurface information would be obtained for all structures. Also, for final design, investigations are required to determine (a) the quantity and

suitability of the waste material forming the fill at the south end of the site for dike construction, (b) the availability and suitability of pervious materials and other impervious materials required for dike construction, and (c) the need for riprap on the river slope of the industrial waste fill area at the south if material is obtained from this area for dike construction.

CORPS OF ENGINEERS — U. S. ARMY



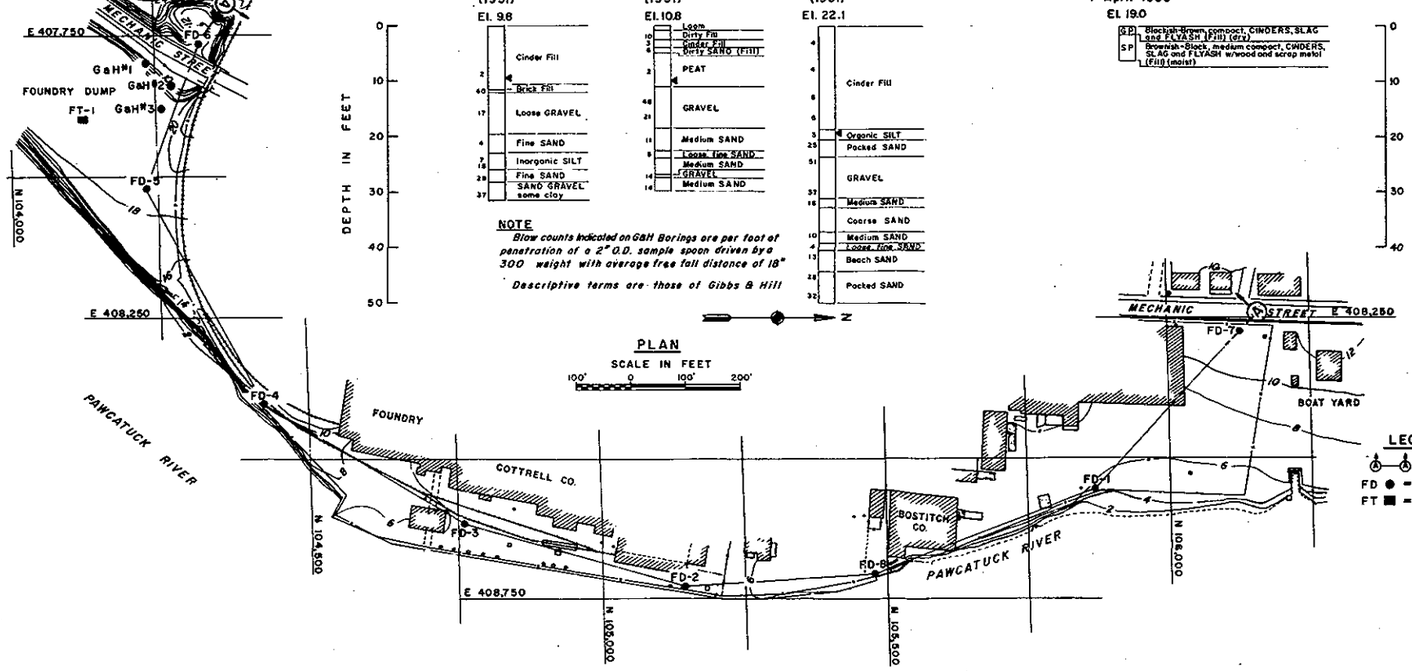
GEOLOGIC SECTION A-A
(LOOKING WEST)



GENERAL LOCATION MAP
SCALE IN MILES
5 0 5 10

TYPICAL LEGEND FOR GRAPHIC LOGS

FD-7 — Type and number of exploration
28 March 1958 — Date exploration completed
El. 11.0 — Elevation of ground surface at time of exploration
Subsurface water level in boring at time of exploration.
SM — Group letter symbol according to Unified Soil Classification System.
NR — No Recovery or unsatisfactory soil samples recovered.
NS — Not Sampled (Core-drilled, blasted and/or washed-bored)
20 — Blows per foot of penetration considered most representative, usually within a 5-foot drive using a 300 or 350 pound hammer with a free fall of about 18 inches on a 2", 2½" and 3" O.D. size sample spoon equipped with bevelled and sharpened drive shoe.
9 — Blow Count not recorded or not considered representative



NOTE
Blow counts indicated on G&H Borings are per foot of penetration of a 2" O.D. sample spoon driven by a 300 weight with average free fall distance of 18"
Descriptive terms are those of Gibbs & Hill

PLAN
SCALE IN FEET
100' 0 100' 200'

LEGEND FOR PLAN
A—A Location of Geologic Section
FD ● = Foundation Test Boring
FT ■ = Foundation Test Pit

NOTES

Elevations refer to mean sea level datum
Contour interval is 2 feet
Subsurface water levels in the explorations may be subject to tidal fluctuation
Borings indicated G&H #1 to G&H #3 were made by Gibbs and Hill, Inc. Engineers. May 1951.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

PREPARED BY C&H
DRAWN BY RDB
CHECKED BY REC
CHIEF NED LABORATORIES
CHIEF, HURRICANE UNIT
CHIEF, PLANS & SPEC. BRANCH
CHIEF ENGINEERING DIV.

HURRICANE SURVEY
PAWCATUCK, CONNECTICUT
GEOLOGY

APPROVED
LT.COL., C.E. ASST TO DIVISION ENGINEER
DATE JULY 1958

TO ACCOMPANY REPORT DATED 6 OCTOBER 1958

SCALE AS SHOWN
DRAWING NUMBER
PAC - 2 - 1000
SHEET 1 OF 1

PLATE D-1

APPENDIX E

DESIGN STUDIES AND COST ESTIMATES

APPENDIX E

DESIGN STUDIES AND COST ESTIMATES

INTRODUCTION

E-1. This appendix presents details of design features and cost estimates for the selected plan of hurricane protection for the principal industrial portion of Pawcatuck, Connecticut. The principal features of the plan are shown on Plates E-1 and E-2.

SURVEYS AND EXPLORATIONS

E-2. The design and cost estimates for the selected plan are based on topographic surveys and subsurface explorations accomplished in 1958, on Army Map Service maps, scale 1:25000, and on town sewerage and drainage maps. A total of eight land borings, described in Appendix D, were made along the considered alignments of the plan of protection.

DESIGN CRITERIA

E-3. The structures have been designed for protection against a Standard Project Hurricane Flood. Both the design criteria and the selected top elevations are shown in Table E-1, below. Appendix B contains further details of the design tidal flood.

The design of structures has followed published standards of the Office of the Chief of Engineers.

TABLE E-1

DESIGN CRITERIA AND SELECTED TOP ELEVATION

Stillwater elevation (feet above m.s.l.)	16.7
Maximum wave height (feet)	Insignificant
Selected top elevation of structures (feet above m.s.l.)	17.0

SELECTED PLAN OF PROTECTION

E-4. DESCRIPTION OF PLAN

a. General. The selected plan of protection (see Plate E-2) consists of a dike and land wall system, 2,700 feet long, extending along the west bank of the Pawcatuck River, tying into high ground south of the Cottrell plant and into the railroad embankment north of the Bostitch plant. Included in the plan of protection are the following structures:

(1) A 40,000 gpm pumping station located on the grounds of the Cottrell plant.

(2) Two highway stoplog structures, 44± feet in width and varying in height from 6 to 9 feet.

The alignment and location of all structures are shown on Plates E-1 and E-2.

b. Dike and Wall. The dike would be of earth-fill construction, protected on the river side by rock fill, and on the landward side by a blanket of gravel, with a top elevation of 17.0 feet above mean sea level and a paved top width of 10 feet. The land wall portion of the protective system would be of the T-Wall type construction. For details see Plate E-2.

c. Pertinent Data. Pertinent data for the selected plan of protection are summarized in Table E-2.

TABLE E-2

PERTINENT DATA

HURRICANE PROTECTION PLAN

Pawcatuck, Connecticut

Dike	
Type: Earth-fill, rock faced river side and gravel faced on landward side and paved crest	
Length	2,386 feet
Top elevation	17.0 feet, m.s.l.
Top width	10 feet
Average height	15 feet
Side slopes	1 on 2.0
Wall	
Type: Concrete T-Wall	
Length	208 feet
Top elevation	17.0 feet, m.s.l.
Pumping Station	
Structure: Brick and concrete block	25.33 x 30.33 ft.
Capacity	40,000 g.p.m.
Sluice gates	
Number	2
Size	4 x 4 ft.
Stoplog Structures	
Number	2
Width of opening	44 feet±
Height of opening	6 to 9 feet

E-5. MODIFICATION TO SEWERAGE AND DRAINAGE FACILITIES

The construction of the proposed plan of protection would cause disruption of all drains, sewers, and interior drainage throughout the area behind the protective works, thus necessitating the construction of an interceptor sewer along the toe of slope of the dike. The interceptor sewer would carry all sewage, interior runoff, and industrial wastes to an inlet chamber built in conjunction with the pumping station. At this point the flow would be directed, by means of sluice gates, to pass through the pumping station during times of flooding and through a 48 inch outfall pipe to the river during normal conditions.

E-6. LANDS AND DAMAGES

The furnishing of necessary lands and rights-of-way, which will be one requirement of local cooperation, has been estimated upon the basis of a field reconnaissance and the application of current market values as determined from a study of a number of recent sales in the general area. The estimate includes the payment of severance damages, and acquisition costs. The lands and improvements to be acquired, and the land upon which either temporary or permanent easements will be secured, are summarized below:

Land:

Acquired in fee, for structures	2.7 acres
Construction easements, temporary	1.0 acres
Permanent easements	None
Total	3.7 acres

E-7. RELOCATIONS

The construction of protective structures would not require the relocation of any highways or railroads. The existing 8 inch water main and 6 inch gas main in Mechanic Street would have to be diverted around the two stoplog structures of the project.

E-8. GEOLOGY OF SITE

The geology of the area and the foundation conditions for the protective structures are discussed in Appendix D. The results of the subsurface explorations are shown on Plate D-1.

E-9. AVAILABLE MATERIALS

Adequate quarry sites are available nearby for supplying the rock fill protection for the dike system. Fill material is available in sufficient quantities to form the dike. For detailed information on availability of construction materials within the Pawcatuck area see Appendix D.

E-10. PLAN OF CONSTRUCTION

The construction of the selected plan of protection would require about one year. The construction schedule, predicated on the erection of the pumping station and modification of sewerage and drainage lines, would be generally as follows:

a. Site preparation, modification to existing sewerage and drainage lines, relocation of utility mains and construction of the pumping station would be accomplished during the first portion of the construction year.

b. The stoplog structures, land walls, and dike system could be constructed once the modification to sewerage and drainage lines had been accomplished.

c. The overall construction program would be completed in one year.

BASIS OF ESTIMATES OF FIRST COST AND ANNUAL CHARGES

E-11. COST ESTIMATES

The cost of the plan has been estimated on the basis of a design which will provide economical and safe structures. Embankment quantities have been made on the basis of the typical cross sections and details shown on Plate E-2 and include allowance for settlement.

E-12. UNIT PRICES

Unit prices are based on averages for similar types of projects either constructed, under construction, or under contract in New England and, where applicable, similar construction in other parts of the country. Adjustments have been made for the availability and sources of material required. The adopted unit prices, which are on a 1958 price level basis, also reflect adjustments to include minor items of work.

E-13. CONTINGENCIES, ENGINEERING AND OVERHEAD

The estimate includes a 20 percent allowance to cover contingencies. The cost of engineering, design, supervision and administration are estimated lump sums based on knowledge of the site and experience.

These items of cost for various phases of the plan are as shown in Table E-3.

E-14. LOCAL CONTRIBUTIONS

Local interests would be required to contribute 30 percent of the first cost of the project, comprising (1) a cash contribution to the United States, presently estimated at $86,000, and (2) lands, easements, rights-of-way and relocations necessary for the construction of the project, presently estimated at $90,000

E-15. ANNUAL CHARGES

The estimate for annual charges is based on 2.5 percent interest on the total investment and amortization of the investment over a period of 50 years. The total investment, Federal plus non-Federal, equals the first costs plus 2.5 percent interest for 6 months or one-half of the estimated construction period of one year. An allowance of $200 for the loss of taxes on lands is included in the annual charges. Costs of maintenance and operation of the project are based on a knowledge of the site and costs of similar projects.

FIRST COSTS AND ANNUAL CHARGES

E-16. FIRST COSTS

The first cost of the selected plan of protection is estimated at $595,000, of which $419,000 would be borne by the United States. Local interests would be required to contribute 30 percent of the first cost of the project, comprising (1) a cash contribution to the United States, presently estimated at $86,000, and (2) lands, easements, rights-of-way and relocations necessary for the construction of the project, presently estimated at $90,000.

E-17. ANNUAL CHARGES

The total annual charges for the selected plan of protection amount to an estimated $27,000. Of this amount $15,000 represents Federal annual charges and $12,000 non-Federal. The determination of annual charges is shown in Table E-4.

TABLE E-3

ESTIMATED FIRST COSTS
(1958 Price Level)
HURRICANE PROTECTION PLAN
Pawcatuck, Connecticut

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
Dike, Land Wall and Pumping Station				
Preparation of Site	2	acre	L.S.	$ 1,000
Earth Excavation, Common	6,500	c.y.	2.00	13,000
Earth Fill	32,800	c.y.	0.70	23,000
Rock Fill	4,860	c.y.	7.00	34,000
Gravel	19,000	c.y.	3.00	57,000
Walls				
Concrete Reinforced	300	c.y.	80.00	24,000
Stoplog Structures				
40 ft. wide x 6 ft. high	1	ea.	13,000	13,000
40 ft. wide x 8 ft. high	1	ea.	19,000	19,000
Pavement	3,000	s.y.	2.00	6,000
Pumping Station	1	job	L.S.	96,000
Drainage Facilities	1	job	L.S.	51,000
Miscellaneous		L.S.		10,000
Sub-total				347,000
Contingencies				69,000
				416,000
Engineering and Design				42,000
				458,000
Supervision and Administration				37,000
				495,000
Preauthorization Survey Studies				10,000
TOTAL COST - Dike, Land Wall and Pumping Station				$505,000
Relocation of Gas and Water Utilities				
Relocation of Gas and Water Utilities	1	job	L.S.	$ 10,000
Lands and Damages				
Land (in fee)	2.7	acre	L.S.	$ 10,000
Severance Damage	1	job	L.S.	53.000
Sub-total				$ 63,000
Contingencies				12,000
				$ 75,000
Resettlement Cost				1,000
Acquisition Cost				4,000
TOTAL COST - Lands and Damages				$ 80,000

TABLE E-3 (Cont'd)

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
Summary				
Dike, Land Wall and Pumping Station				$505,000
Relocation of Gas and Water Utilities				10,000
Lands and Damages				80,000
TOTAL FIRST COST				595,000
Estimated First Cost to U.S.				419,000
Estimated First Cost to Local Interests				176,000(1)

(1) Includes estimated costs of $80,000 for lands and damages, $10,000 for relocation of utilities, and a local cash contribution presently estimated at $86,000. This local cash contribution when added to the estimated cost of lands, damages and relocation of utilities represents a local interests share of 30 percent of the first cost of the project.

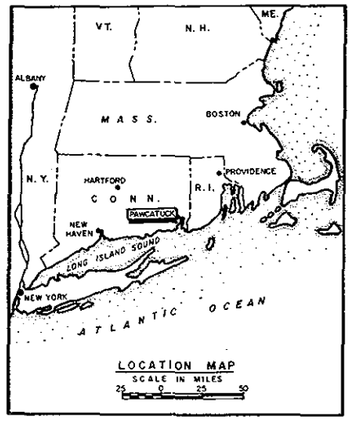
TABLE E-4

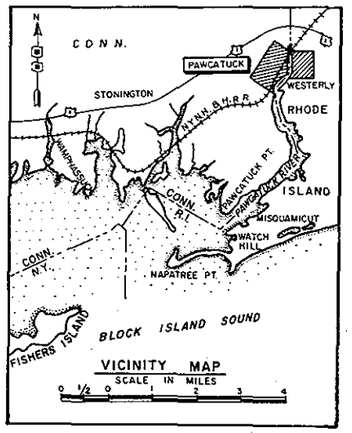
ESTIMATED ANNUAL CHARGES
(1958 Price Level)
HURRICANE PROTECTION PLAN
Pawcatuck, Connecticut

Federal Investment			
Total Federal First Cost			$ 419,000
Interest during Construction			5,000
Total Federal Investment			$ 424,000
Federal Annual Charges			
Interest on Investment, 2.5%			11,000
Amortization, 1.026%			4,000
Total Federal Annual Charges			$ 15,000
Non-Federal Investment			
Contributed Funds			86,000
Lands and Damages			80,000
Relocation of Gas and Water Utilities			10,000
Total Non-Federal First Cost			$ 176,000
Interest during Construction			2,000
Total Non-Federal Investment			$ 178,000
Non-Federal Annual Charges			
Interest on Investment 2.5%			4,000
Amortization, 1.026%			2,000
Major Replacements, Auxiliary Equipment for Pumps			200
Maintenance and Operation			
Salaries	1,200		
Supplies	300		
Embankment and General	500		
Concrete Features	200		
Pumping Station	1,100		
Drainage	2,000		
Stoplogs	300		
		$	5,600
Estimated Tax Losses			200
Total Non-Federal Annual Charges		$	12,000
TOTAL ANNUAL CHARGES			27,000
TOTAL ANNUAL BENEFITS			57,400
RATIO OF ANNUAL BENEFITS TO ANNUAL CHARGES			2.1 to 1.0

CORPS OF ENGINEERS

U. S. ARMY





U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
R.J.M.	R.J.M.	J.B.G.

PROJECT ENGINEER

CHIEF, HURRICANE UNIT

SUBMITTED BY

CHIEF, PLANS & SURVEYS BRANCH

APPROVED BY

CHIEF ENGINEERING DIV.

HURRICANE SURVEY
PAWCATUCK, CONN.
LOCAL PROTECTION
GENERAL PLAN

APPROVED

LT.COL., C.E. ASST. TO DIVISION ENGINEER

DATE JULY 1958

TO ACCOMPANY REPORT
DATED 6 OCTOBER 1958

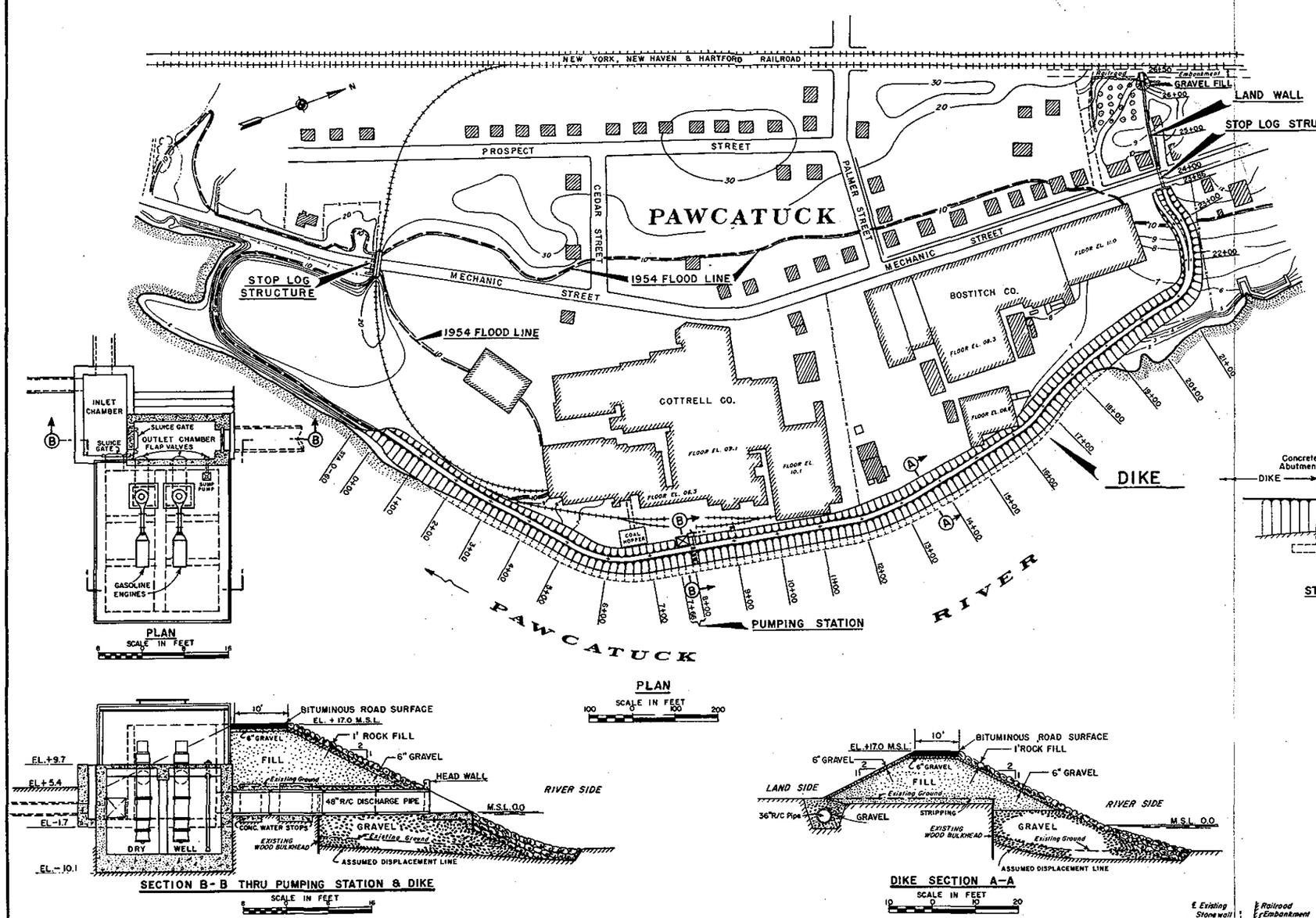
SCALE AS SHOWN

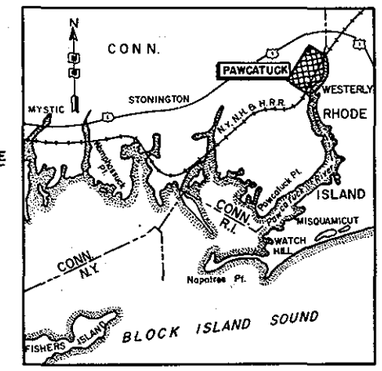
DRAWING NUMBER
PAC-1-1001

SHEET

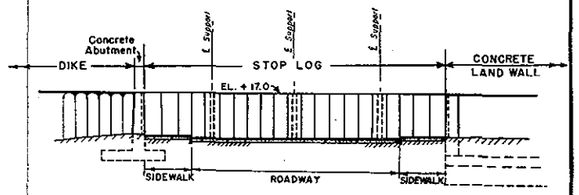
PLATE 2 & E-1

CORPS OF ENGINEERS U. S. ARMY

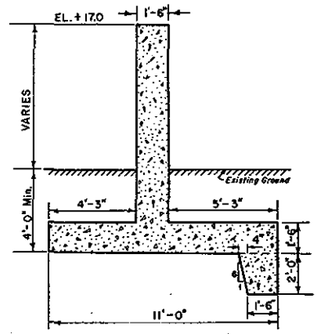




VICINITY MAP
SCALE IN MILES



STOP LOG ARRANGEMENT AT ROADWAY, NORTH
SCALE IN FEET



TYPICAL CONCRETE LAND WALL
SCALE IN FEET

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
R.J.M.	R.J.M.	J.B.G.

PROJECT ENGINEER
CHIEF, HURRICANE UNIT
SUBMITTED BY
CHIEF, P, E&A & NAVIGATION BRANCH
APPROVED
CHIEF ENGINEERING DIV.

HURRICANE SURVEY

PAWCATUCK, CONN.

LOCAL PROTECTION PLAN

APPROVED DATE JULY 1958
LT. COL., C.E. ASST. TO DIVISION ENGINEER

TO ACCOMPANY REPORT
DATED 6 OCTOBER 1958

SCALE AS SHOWN
DRAWING NUMBER
PAC - 1 - 1002
SHEET 1 OF 1

PLATE E-2

APPENDIX F

PUBLIC HEARING AND VIEWS OF OTHER AGENCIES

APPENDIX F

PUBLIC HEARING AND VIEWS OF OTHER AGENCIES

F-1. GENERAL

This appendix presents a digest of the public hearing and includes available letters and statements indicating the views of other agencies and individuals, not represented at the hearing, on the plan of protection.

F-2. DIGEST OF PUBLIC HEARING

A public hearing was held for Pawcatuck by the Division Engineer in Stonington, Connecticut on 20 February 1958 to give all interested parties an opportunity to express their views concerning the character and extent of hurricane protection desired and the need and advisability of its execution. Information was presented at the beginning of the hearing on preliminary studies by the Corps of Engineers including an alternative plan and cost estimates. A digest of the hearing is attached together with abstracts of correspondence from local interests pertaining to the recommended plan of protection.

F-3. LETTERS OF COMMENT

a. State of Connecticut, Board of Fisheries and Game - letter signed by Mr. Lyle M. Thorpe, Director, dated 2 June 1958.

b. State of Connecticut, Development Commission - letter signed by Mr. LeRoy Jones, Assistant Managing Director, dated 21 February 1958.

F-4. LOCAL COOPERATION

a. The Honorable Abraham Ribicoff, Governor, State of Connecticut. Letter dated 26 August 1958.

b. The Honorable David M. Johnstone, Senator, Twentieth District, State of Connecticut and First Selectman, Town of Stonington. Letters dated 19 February 1958 and 4 September 1958.

c. Mr. John J. Curry, Chief Engineer, Water Resources Commission, State of Connecticut. Letter dated 21 February 1958.

DIGEST OF PUBLIC HEARING, PAWCATUCK, CONNECTICUT - 20 FEBRUARY 1958

Speaker	Interest Represented	Protection Desired	Reasons Advanced and Other Remarks
The Honorable David M. Johnstone	State Senator from Twentieth Senatorial District and First Selectman, Town of Stonington	Endorsed the plan of protection proposed at the hearing.	Stated that there was no difference between salt water flooding and fresh water flooding, however, in the past there had been "definite discrimination against those who would be protected against flooding by salt water, while there had been a readiness to protect against fresh water flooding". Further stated that "this project is an ideal opportunity to demonstrate the worthiness of a salt water flooding protection program". Stated that the "Town of Stonington will participate in the cost of the project". Presented a statement from the Stonington Democratic Town Committee, signed by James A. Pizzaro, urging that the project be undertaken with the utmost speed.
The Honorable Edward P. Faulk	State Representative from the Pawcatuck area	Favored any project which would provide protection for industries both present and future in Pawcatuck.	Stated that a large percentage of the people employed by industries in Pawcatuck come from neighboring towns.

F-2

Mr. Charles J. Lazarek Chairman	Board of Finance Town of Stonington	"Thoroughly" in favor of the suggested plan.	Protection of the two plants (Bostitch and Cottrell) is vital to the economic interests of the area. Also, if protection were assured, something could be done with the now vacant Bostitch plant.
Mr. Everett A. Engstrom Tax Assessor, Town of Stonington	Individual	Endorsed the suggested plan of protection.	Presented a statement which showed the estimated market value of the property to be protected from tidal flooding in the Town of Pawcatuck by the suggested plan of protection. The present estimated total value is $6,747,000, and if the Bostitch plant were occupied it would be $7,500,000. Stated that tidal flooding was one factor which caused the Bostitch Company to vacate their building, which in turn caused the town to lose a million dollars in personal property; that tidal flooding protection would attract new industry to the vacant Bostitch plant and protect the Cottrell holdings; that the Cottrell Company pays about 20% of the town taxes as well as providing a living for many residents of the town and the areas across the river in Rhode Island.

Mr. John F. Gallagher Counsel for the Town of Stonington	Individual	Favored suggested plan of protection	Endorsed the statements of Messrs. Johnstone, Faulk, Lazarek and Engstrom.
Mr. Robert C. Perkins Chairman	Republican Town Committee	Favored the project provided it did not in any way excessively burden the taxpayers of the Town of Stonington.	The project is of utmost importance in protecting the Cottrell and Bostitch plants, thereby protecting the jobs of hundreds of workers, as well as the continued economic growth of the town.
Mr. John J. Donahue Fire Chief, Town of Pawcatuck	Individual	Favored the suggested plan of protection.	Pawcatuck would be a ghost town if the Cottrell Company moves out. Suggested that everybody should be in favor of the project and that something should be done as no town can get along without its industry. Asked question, if it were found necessary to pump behind the dike, would it be possible or practical to have the pumps so arranged that in case of fire they could be used for fire protection, thereby serving a dual purpose by drawing water from the river, as well as pumping from behind.
Mr. James M. Spellman Chairman	Zoning Commission Pawcatuck Fire District	Favored protection for the area.	Stated that the American Trade Company was lost as a result of the 1938 hurricane damage. Requested full cooperation from the Corps of Engineers, and stated, "we will certainly do all we can".

Mr. John L. Monti President	Westerly Town Council	In favor of hurricane protection.	Stated that he did not come within the area of proposed protection but he would like to see the area protected so that the Westerly people can come to work in the plants. Several hundred people in the Westerly area are working in the Cottrell plant and several hundred worked for Bostitch.
Mr. Howard E. Crouch Chairman	Industrial Development Committee, Pawcatuck	Endorsed the suggested plan of protection.	The Committee recommended authorization of protection and approval of appropriation of funds for development of the project. The economic life of the community is severely affected by the Cottrell plant and the Bostitch facilities for the maintenance and support of over 5,000 people in the immediate area. The towns physical condition will be vitally affected if this flooding condition is not corrected. Presented a petition signed by local merchants endorsing the project.

Mr. Warren M. Greenwood Executive Vice-President	Westerly-Pawcatuck Chamber of Commerce	Endorsed the suggested plan of protection.	The Chamber of Commerce is 100% for anything that will be of benefit to the existing industries. Requested that the project go ahead with all possible speed. The project would save the Cottrell Company Division of Harris-Intertype many thousands of dollars in time and equipment. The project would go a long way towards retaining the present industry, help in selling the vacant plant, and attracting new industry.
Mr. Charles W. Greenwood Assistant Works Manager	Cottrell Company	Endorsed the suggested plan of protection.	Presented letters from the Vice-President and General Manager of the Cottrell Company, the Pattern Makers' League, CIO-AFL, Cottrell Company, Pawcatuck, Connecticut, the International Molders and Foundry Workers Union of North America, AFL-CIO, Local 363, and a petition of about 500 signatures of local residents. All endorsed the suggested plan of hurricane protection.
Mr. Gordon Michie Machinist	International Association of Machinists	Endorsed the suggested plan of protection.	Interested in any plan that would give protection to the earnings of the employees.

Mr. Joseph J. Purtill Secretary	Pawcatuck Lions Club	Endorsed the suggested plan of protection.	Presented a letter which stated that the suggested hurricane protection project would protect over $7,000,000 worth of property; contribute to the employment of more than 1300 workers in the area; provide an incentive for enlargement of the $13,000,000 Cottrell Company business; and aid in securing an industry to replace the Bostitch plant.
Mr. Joseph A. Vargas	Individual	Favored the suggested plan of protection.	Stated that according to his grandfather the 1815 hurricane was a foot higher than the 1938 hurricane.
Mr. Hiram Kendall Manager	Industrial National Bank		Presented a letter signed by the Executive Vice-President of the Industrial National Bank. (See letter inclosed.)
Mr. Eugene McKenna President	Bargaining Unit, Cottrell Company	Endorsed the suggested plan of protection.	Stated that the Unit is representative of 400 members, all employees of the Cottrell Company, and that the employees lose time, which affects their pay, on account of hurricane warnings.

Mr. Morgan Stewart	Individual	Favored the suggested plan of protection especially as it would protect some residences as well as industry.	Stated that, as a former newspaperman he had attended hearings the greater part of his life, and that this was the only meeting he had ever attended where the "opinion was unanimous".
Mr. Henry L. Babcock Secretary	Pawcatuck Board of Trade	Endorsed the suggested plan of protection.	Presented a resolution which stated that, - This project is considered very essential for the continuous economic well-being of the area, and that the business and industrial community is seriously affected by the continuous tidal flooding of the Bostitch and Cottrell plants.
Mr. Carol Campbell	Individual	Endorsed the suggested plan of protection.	
Mr. Mario P. Nardone	Sherman Lumber Company		Requested information as to what effect the barrier would have on the opposite side of the river, the Westerly side.
Mr. Richard Hames Fisheries Biologist	Connecticut State Board of Fish and Game		Requested information concerning utilization of the suggested plan for fishing, boating, etc. - that is, could people get to the water for boat launching from trucks somewhere along the high land. Suggested that the Federal Government pay for construction of any works along this line and that local interest develop the land.

Mr. Elwell B. Thomas	Individual		Requested that consideration be given to the fact that salt water flooding does more damage than fresh water flooding.
Mr. William W. Beresford	Individual	Endorsed the suggested plan of protection.	Requested information concerning the flooding of all land north of the barrier during the times of high water, and the possibility of extending the dike up to the bridge and avoid flooding Mechanic Street.

LETTERS AND STATEMENTS FORWARDED TO THE DIVISION ENGINEER, NEW ENGLAND DIVISION

RELATING TO THE PLANS OF PROTECTION SUGGESTED AT THE PUBLIC HEARING

Signed by	Interest Represented	Date of Letter and Remarks
Mr. R. John Griefen Vice-President	R. M. Bradley & Co., Inc. Real Estate	May 8, 1958. Letter requesting that the proposed hurricane project be pushed forward in every way possible. Also, inclosed copy of letter to the Connecticut Development Commission, same date, requesting their assistance in furthering the project.

STATE OF CONNECTICUT
BOARD OF FISHERIES AND GAME
2 WETHERSFIELD AVENUE · HARTFORD, CONNECTICUT

ADDRESS ALL MAIL TO
E OFFICE BUILDING, HARTFORD

June 2, 1958

Lt. Col. Miles L. Wachendorf
Army Engineer Division, New England
Corps of Engineers
150 Causeway St.
Boston 14, Mass.

Dear Col. Wachendorf:

Reference is made to your letter of May 19th announcing studies to determine the possibility of providing hurricane protection in Pawcatuck, Connecticut. We have carefully studied the plan under study which you kindly provided us and we believe that these would not be detrimental to the wildlife interest; therefore, we approve the plans as submitted and have no suggestions for any changes.

Very truly yours,

Lyle M. Thorpe
Director

LMT/B

STATE OF CONNECTICUT
DEVELOPMENT COMMISSION
STATE OFFICE BUILDING · HARTFORD 15, CONNECTICUT

February 21, 1958

Brigadier General Alden K. Sibley
Division Engineer
U. S. Army Engineers, New England Division
Corps of Engineers
150 Causeway Street
Boston 14, Massachusetts

Dear General Sibley:

Relative to the hearing which was held on February 20 at Stonington, Connecticut concerning the building of dikes at the Cottrell and Bostitch plants in Pawcatuck, Connecticut, this Commission does recommend that favorable consideration be given to do this particular project.

Currently the employment situation in much of this state is such that the state and federal governments should do everything possible to protect present and future manufacturing operations along the shoreline.

The Bostitch property and area is one that has an excellent potential for employing manufacturing workers in both Connecticut and Rhode Island and thus deserves particular attention at this time.

I hope you will render favorable consideration of this recommendation.

Sincerely yours,

LeRoy Jones

LeRoy Jones
Asst. Managing Director

LJ:ssg

ABRAHAM RIBICOFF
GOVERNOR

STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

August 26, 1958

Brigadier General Alden K. Sibley
New England Division Engineer
Corps of Engineers, U. S. Army
150 Causeway Street
Boston 14, Massachusetts

Dear General Sibley:

This will refer to your letter of August 22 requesting opinion concerning the report on hurricane tidal-flood protection at Pawcatuck, Connecticut.

I have consistently supported sound programs for the protection of the people of Connecticut and their development against damages from floods and hurricanes. The Stonington area has suffered heavy damage from tidal flooding during past hurricanes and protection against the recurrence of such damages is needed.

At the present time there are no specific State funds available for participating in such projects in accordance with the requirements as contained in your letter. However, the executive, legislative and administrative agencies of the State have cooperated and participated in sound projects in the past and now there is no reason to assume that the same policies will not be followed in a sound program for the protection of the Stonington area when such a project reaches the stage of construction.

Sincerely,

Abe Ribicoff

Governor

CONNECTICUT STATE SENATE
HARTFORD

IATOR DAVID M. JOHNSTONE
Twentieth District

COMMITTEES
Elections, Chairman
Fish and Game
Water Resources and Flood Control
Public Health and Safety

February 19, 1958

U. S. Corps, Army Engineers
150 Causeway Street
Boston, Massachusetts

Gentlemen:

Re: Pawcatuck River Hurricane Protection.
As a member of the State Legislative Water Resources and Flood Control Committee, I am aware of the great interest of the Federal government as represented by the Department of Engineers, in flood control projects.

The 1955 floods in Connecticut and the many proposed flood control projects arising therefrom have demonstrated to us again, your deep interest in flood control even though, as in the case of the 1955 floods, they may only occur once in some fifty years.

We have before us in the Pawcatuck hurricane flood protection project, a project that is certainly as worthy as many of the other flood projects throughout the State. In this particular case, the flooding experience has been on the average of every five years which is considerably more often than many other flood protection projects.

To me, there is no difference between being flooded by salt water than there is by fresh water. However, to date, there has been definite discrimination against those who would be protected against flooding by salt water while there has been a readiness or even an eagerness to protect against fresh water flooding. I believe that we have in this project, an ideal opportunity to demonstrate the worthiness of a salt water flooding protection. It is not an expensive project, but yet has a very high benefit-cost ratio.

As far as a contribution from the State of Connecticut is concerned, I can only speak as one member of the Legislature, but I feel that any contributions to salt water flood protection should be just as generous as those for any other type of flood protection in the State.

Yours very truly,

David M. Johnstone

David M. Johnstone
Senator, Twentieth District

Town of Stonington, Conn.

SELECTMEN'S OFFICE, TOWN HALL

Telephone Mystic JEfferson 6-9361

September 4, 1958

U. S. Army Engineer Division
150 Causeway Street
Boston 14, Massachusetts

Gentlemen:

Ref. File: NEDGW
I am replying to your letters of August 22 and 26 regarding an opinion about the willingness and ability of local interests to meet the requirements of cooperation for hurricane tidal-flood protection at Pawcatuck and Mystic, both in the Town of Stonington.

The matter was brought up in a recent meeting of the Board of Selectmen and it is it's opinion that the Town would be unwilling and unable to meet the entire 30% contribution requested of local interests in both cases. However, it is still the Board's opinion that there is willingness on the part of the Town to bear part of the cost of the project as well as its maintenance.

The exact percentage can't be set at this time, and of course, would have a great deal to do with the contribution on the part of the State of Connecticut which from your point of view is part of the 30% contribution of local interests. The State Legislature has not had a State-aid salt water flood protection program before it, although it is anticipated that the next session in January 1959 will have such a request. As far as the Town of Stonington is concerned, it will have to wait for the outcome of this legislation.

Yours very truly,

David M. Johnstone

David M. Johnstone
First Selectman

DMJ:EFC

Town of Stonington, Conn.

SELECTMEN'S OFFICE, TOWN HALL
Telephone Mystic Jefferson 6-9361

February 19, 1958

U. S. Army Engineers
150 Causeway Street
Boston, Mass.

Gentlemen:

Re: Pawcatuck Hurricane Protection.
I believe that the proposed project for hurricane flood protection in the Pawcatuck River that will involve the Cottrell Company, Bostitch, and a number of private homes is necessary for the safety from flood of the area and that it is economically justified. The project protects the two largest taxpaying and employing industries in the Town. Besides the direct benefit of the dike to the two plants, we have the indirect benefits to the facilities serving the plant as well as the wage earners and all of the services serving them.

Although the exact proportion of the cost of the project between the Federal, State and local interests are not known at this time, I feel it possible to say that local Town interests will contribute to the cost of the project.

It is my understanding that this local interest contribution can be made by those directly effected such as Cottrell's and Bostitch, other private interests in the Town as well as local Town tax money which, of course, would have to be voted at a Town Meeting.

Yours very truly,

David M. Johnstone
First Selectman

DMJ:EFC

STATE OF CONNECTICUT
WATER RESOURCES COMMISSION
STATE OFFICE BUILDING · HARTFORD 15, CONNECTICUT

February 21, 1958

The Division Engineer
New England Division
150 Causeway Street
Boston 14, Massachusetts

Dear Sir:

Reference is made to your letter of 30 January requesting comments on your proposed hurricane protection plan for the industrial area of Pawcatuck, Connecticut.

This proposed protection plan was presented to the Water Resources Commission at its meeting on February 3, 1958. The Commission, after considerable discussion, voted "approval of the general idea" and directed that a statement to this effect be made at the public hearing. In addition to this comment on the plan in general, you request comment on the possible participation in the cost by the State and local interests.

Although the federal policy on such participation has not yet been established by Congress, the Statutes of the State of Connecticut anticipate this type of project and under Sections N209 and N207 establish a basis of cooperation and participationby both this Commission and the Town Flood and Erosion Control Board. When federal policy is finally established it should require only minor changes if any in the Statutes.

At the present time there are no funds directly applicable for State participation in such projects. Your past experience should indicate that the State's attitude as expressed by both executive and legislative branches toward participation in improvement-protective projects has been progressive.

Very truly yours,

John J. Curry
Chief Engineer

JJC/jb